ECOlogical observing System in the Adriatic Sea: oceanographic observations for biodiversity

Priority Axis 3: Environment and cultural heritage

Specific Objective 3.2: Contribute to protect and restore biodiversity

D4.4.1 Report on the interactions, synergies and gaps among the WFD, MSFD and H&BD for an effective management of the marine ecosystems

WP4 – Establishing the Ecological Observing System in the Adriatic Sea (ECOAdS)

A4.4 – Interconnections among indicators of WFD, MSFD and HBD

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CONTENT

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1. INTRODUCTION

1.1 Activity 4.4 and deliverable 4.4.1

This deliverable is the result of the Activity 4.4 - "Interconnections among indicators of WFD, MSFD and H&BD". In accordance with what is reported in the application form, deliverable 4.4.1 aims at analysing and reporting the interactions and synergies among the Habitats and Birds directives (HD and BD; EEC 1992 and EC 2009, respectively), the Water and the Marine Strategy Framework directives (WFD and MSFD; EC 2000 and EC 2008, respectively) for an effective management of the marine ecosystems. In addition, it aims at contributing to the building up of a coherent ecosystem-based indicator system for threatened species and habitats, which recognises, from one side, interactions among species, communities, habitats and ecological processes and, from the other, the integration of the ecological observatories carried out on specific sites with those in the wider offshore area.

1.2 Work outline

In this deliverable, in paragraph 2, we introduce the concept that lags behind the definition of marine ecological observatories. We then delineate the essential attributes that the Adriatic ecological observatory ECOAdS includes as a decision-support tool for the responsible authorities and agencies of Natura 2000 (N2K) sites to favor the overcoming of the identified issues that hinder N2K implementation and efficacy.

In paragraph 3, we report the analysis of synergies and complementarities among the main EU directives addressing marine conservation (WFD, MSFD and the H&BD). We also resume the main concepts on which the Essential Oceanographic Variables (EOV) and Essential Biodiversity Variables (EBV) global frameworks have been built and developed, linking their implementation to ECOAdS, from the perspective of a possible harmonization also with the directives.

In paragraph 4, we resume the generic conceptual model previously developed and proposed in deliverable 3.3.1. Starting from its framework, we zoomed in on the monitoring descriptive indicators utilized by the directives to monitor the state of the aquatic environments and we make a first attempt of harmonization among them, focusing our attention on terminology aspects. We also review the monitoring variables already collected at the scale of the N2K sites selected in ECOSS.

In paragraph 5, we propose an approach to develop a coherent ecosystem-based indicators system for monitoring target species and habitats of N2K sites. This system allows us to bring out possible limitations and opportunities to monitoring and to guide a possible prioritization of monitoring variables to support conservation of target specie and habitats in the N2K sites.

Finally, we draw conclusions and deliver suggestions for implementing a coherent and transnational monitoring framework in the Adriatic Sea, boosted by ECOAdS, to support management and conservation strategies.

To enhance the development and implementation of the management plans and monitoring programs for all N2K sites, it is necessary to consider a set of key elements, all essential to describe the relevant connections that link together the conservation objectives, the environmental components and processes that are the targets of conservation, and the human dimension that interacts with the coastal and marine environment. In this report, numerous key terminologies were adopted to describe all these relationships and the elements that are the subjects of the analysis developed here. They are all fundamental and included as crucial parts of the final outcome of this deliverable. For clarity reasons, in Table 1 we summarized their definitions, which are in line with those adopted in the framework of the ECOSS project (see in particular deliverable D3.3.1).

Table 1. Key terms and summary of their definitions. The full version can be found in Deliverable 3.3.1.

KEY TERMINOLOGY	**ECOSS DEFINITION**
Target species	All rare, threatened or endemic animals and plants targeted for conservation under the Habitats Directive (HD, 92/43/EEC) and Birds Directive (BD, 2009/147/EC).
Ecological processes	A number of biological, physical, and chemical processes, such as primary production and nutrient cycle, that sustain the ecological systems and their biodiversity and allow production and transfer of matter between organisms and the physical environment.

Ecological variables	Descriptive indicators that give information on the status of ecological processes and target species in selected areas (e.g., spatial distribution, density, abundance and biomass, growth and mortality rate of a species).
Physical ocean processes	Physical phenomena occurring in the world oceans and seas, which regulate trend, transport and flux of water, substances and organisms in the marine system.
Oceanographic variables	Descriptive indicators that include physical parameters (e.g. water temperature, salinity, conductivity, current direction), chemical parameters (e.g. dissolved oxygen, pH, dissolved macronutrient concentration), meteorological parameters, and some biological parameters (e.g. chlorophyll a, phyto- and zooplankton abundance and biomass).
Descriptive indicators or monitoring variables	Indicators that describe the environmental state and its change in space and time. They include ecological and oceanographic variables.
Human-induced environmental changes at the local and global scales	They can be various: variation of water temperature, sea level rise, ocean acidification, increased ocean stratification, decreased sea-ice extent, hypoxia. They affect the environmental conditions and the ecological processes irreversibly altering the marine ecosystems.
Ecological monitoring	The process of periodical observations conducted at different spatial and temporal scales, giving information on environmental status.
Oceanographic observing systems	A network of instruments and facilities designed to monitor the state of the sea and to help predicting how marine environments respond to anthropogenic alterations.
Ecosystem services	The contributions of ecosystem structure and function to human well-being, resulting from the interaction with the social components.
Protected area management goals	A long-term objective that describes or envisages the expected conservation state that protected area policies want to achieve and maintain.
Performance indicators	A component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals.

Protected area management objectives	Specific statements that follow the main goal and set out the conditions that management aims to achieve. They are statements of the desired short-term 'outcomes' rather than how to achieve them.
Conservation measures	Management plans or any appropriate statutory, administrative or contractual measures, defined by the law of each Member States, that are finalized to regulate activities, uses and collection of organisms in the protected sites, and maintain biodiversity.
Human activities	All those activities that depend on the ocean and coastal ecosystems for goods and services and that interact and affect the marine habitats and species of the N2K sites.
Public/management authority	Any public institution, private company, NGO, organization or association responsible to manage a protected area.
Stakeholders	All those people who have an interest in the N2K site or its natural resources. Main categories are: government, private sector, and general public.
EU Directives	Legal instruments focused on nature protection and that consider it: the Habitats Directive (HD, 92/43/EEC), the Birds Directive (BD, 79/409/EEC), the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC), Common Fishery Policy (CFP, 1380/2013/EC), Maritime Spatial Planning Directive (MSPD, 2014/89/EU).
ECOAdS	ECOlogical observing system in the Adriatic Sea, which aims at integrating the ecological and oceanographic research and monitoring with the N2K conservation strategies. It is the main outcome of the ECOSS project.

2. THE MARINE ECOLOGICAL OBSERVATORY ECOAdS

Marine Observatories (MOs) are observing, monitoring and experimenting infrastructures globally widespread, conceived to collect high-resolution data to monitor the oceanographic state of the marine environment and its modifications due to climate changes (Crise et al., 2108; Rayner et al., 2019). They have been established to answer to the need of systematic scientifically-based monitoring of our oceans. Indeed, constant monitoring has been recognized as a central requirement for ocean management, to limit the multiple human pressures that are affecting the marine ecosystems and to address climate impacts (Bax et al., 2018; Miloslavich et al., 2018; McQuatters-Gollop et al., 2019). In addition, extended monitoring systems and infrastructures are considered key instruments to support the achievement of the United Nation Sustainable Development Goals (SDGs), especially the UN SDG 14 "Life below water", and the effective protection and restoration of the marine environment (Biermann et al., 2017; Mack et al., 2020). Thus, MOs can inform scientific and evidence-based decisions in marine conservation management, but for doing so they must adopt a more holistic approach by embracing ecological processes and information beyond the oceanographic ones. Oceanographic and ecological processes are entangled and together support marine ecosystems functioning, therefore the first cannot exist apart from the second and must be both monitored and preserved in a good state.

Marine Ecological Observatories (MEOs) represent the needed advancement of MOs, because they broaden the spectrum of observing actions to embrace ecological research and monitoring (Carr et al., 2011; Benedetti Cecchi et al., 2018; Manea et al., 2020). MEOs recognize the ecological connectivity as one of the main driving forces that has to be addressed by conservation management to allow the adequate functioning of all marine ecosystems. Ecological connectivity represents "the degree to which landscapes and seascapes allow species to move freely and ecological processes to function unimpeded" (UNEP, 2019). Ecological connectivity, especially in the fluid marine environment, is crucial because allows the existence of all the complex interconnections among natural processes, species, species and their habitats during their life cycles (Carr et al., 2003; Maxwell et al., 2015; Manea et al., 2019). Within this broad perspective, coherent and operative MEOs are recommended at the European and global level (Benedetti Cecchi et al., 2018; Carr et al., 2011; Duffy et al., 2013; Muelbert et al., 2019).

Because MEOs can deliver great benefits to enhance both the understanding of the marine ecosystems and the assessment of their state and changes over time and space, their presence and actions can really make a difference if coordinated in a way to support the monitoring and management of Natura2000 (N2K) network. Indeed, most of the N2K sites lack of management plans and as a consequence of systematic monitoring activities (Claudet et al., 2020), with monitoring initiatives taken sporadically and mainly in the context of specific, short-term projects. This is true also for most of the N2K sites selected as case studies in ECOSS project, as reported in deliverables 4.1.1 "Report on the characterization of the selected Natura 2000 sites" and 4.1.2 "Report on the relationships between ecosystem-level management". Beyond their primary role in marine environment monitoring, MEOs should be designed to generate knowledge related to the dynamics between the human dimension and the natural systems. For doing so, they should be able to involve researchers, policy makers and members of the civil society, to collect a variety of knowledge and viewpoints to favor innovation and development to answer to the detected needs and to inform marine planning, management, and conservation. Thus, MEOs can offer real support to conservation strategies, helping in setting goals, performance standards and monitoring actions (Manea et al., 2020).

In the Adriatic Sea, the realization of the Ecological observatory ECOAdS is an invaluable tool for the implementation of N2K sites and their management, the 2030 target of the EU biodiversity strategy, the EUSAIR Action Plan, as well as for the implementation of diverse EU Environmental Directives, in particular those that deal with marine conservation and management, meaning, beyond the Habitats and Birds directives (HD and BD; EEC 1992 and EC 2009, respectively) also the Water and Marine Strategy Framework directives (WFD and MSFD; EC 2000 and EC 2008, respectively). Indeed, as reported in deliverable 3.1.1 "Report on assessment of existing ecological monitoring programmes", the Adriatic Sea hosts diverse well-established monitoring programs, acting at different spatial scales, from national to county/region level, and fixed-point observing systems (i.e. pylons, buoys, tide gauges, oceanographic platforms). Especially, the fixed infrastructures can provide multidisciplinary and automated monitoring of coastal and offshore marine areas, with high temporal resolution, for a number of marine and atmospheric variables (Ravaioli et al., 2018; Šepić and Vilibić 2011; Šepić et al., 2017). Overall, the ongoing monitoring observations in the area are mainly linked to the fulfilment of the obligations established by the various EU Directives (mainly WFD and MSFD) or to specific programs and initiatives, such as the Italian Long-Term Ecological Research network, LTER-Italy. They address a wide variety of environmental issues, spanning from the assessment of the quality of transitional, coastal and marine waters to the monitoring of target species (e.g. dolphins and sea turtles) and other biotic components (e.g. plankton, macroalgae, coralligenous assemblages). Nonetheless, all these initiatives are not shared between Italy and Croatia and lack an adequate coordination that could connect the local, the regional, up to the whole Adriatic basin scale, in an integrated and coherent observatory. Thus, ECOAdS represents the opportunity of integrate and coordinate the existing monitoring schemes and systems to provide a more complete picture of the state of the marine environment, N2K sites included, and at supporting N2K network implementation at transnational and regional scale. ECOAdS starts by embracing the fixed-point observing systems located in the pilot study area and of which ECOSS partners are managers and/or direct scientific advisors (Fig. 1).

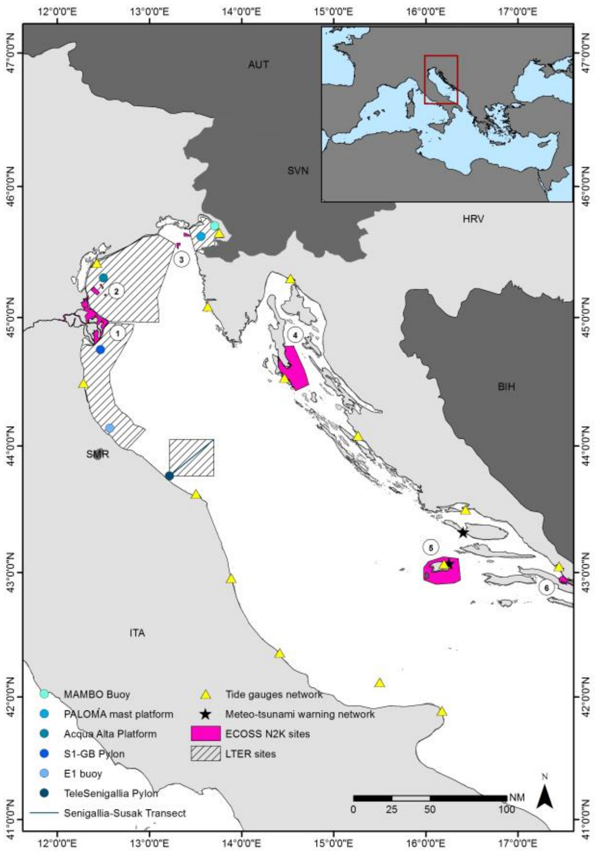

Fig. 1 ECOAdS N2K sites and fixed point observing systems managed by ECOSS project's partners. N2K sites are: 1. Po river delta (IT3270017 and IT3270023), 2. Tegnùe di Chioggia (IT3250047), 3. Trezze San Pietro e Bardelli (IT3330009), 4. Cres-Lošinj (HR3000161), 5. Vis (HR3000469), 6. Mali Ston (HR4000015). Sources: ECOSS N2K sites; Ravaioli et al., 2018; MAPAMED; Meteo-tsunami network; Tide gauges network; LTER-Italy sites. Source Manea et al., 2020.

2.1 The essential attributes of ECOAdS to support N2K network implementation and marine conservation

ECOAdS has been conceived as an instrument able to embrace a holistic approach, based on diverse attributes that should be incorporated in its monitoring coordination system and observation framework, to tackle the main issues for an effective N2K network implementation and to support marine conservation and management at the regional scale (Fig. 2).

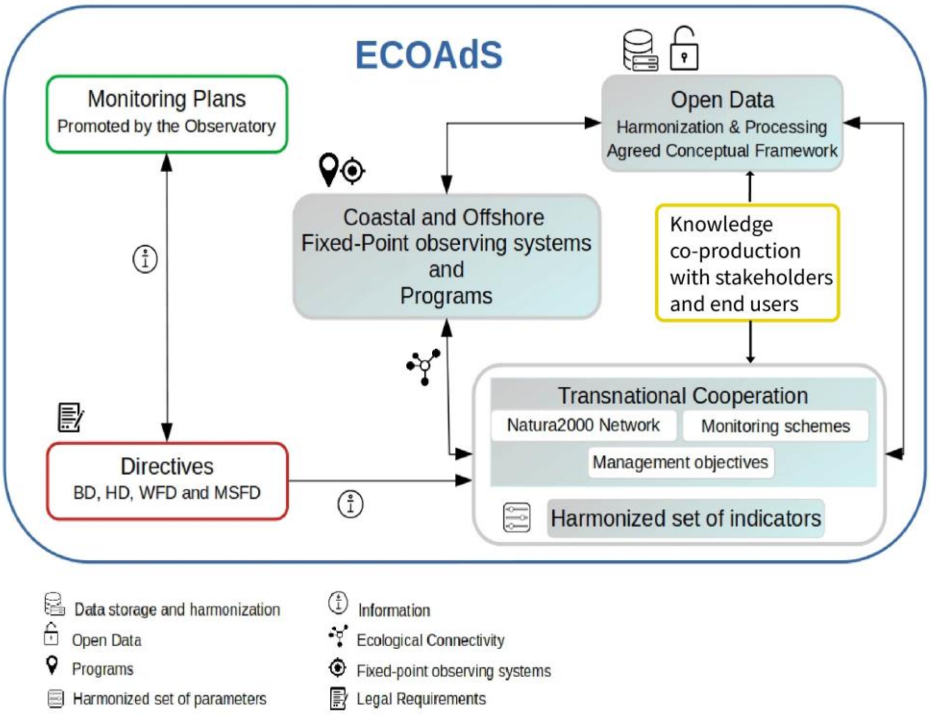

Fig. 2 Schematic view of the essential attributes of ECOAdS to support monitoring programs harmonization.

Four main essential criteria have been distilled to guide the building up of ECOAdS (Manea et al., 2020), which will be detailed in the following sections: (i) adoption of an agreed conceptual framework to monitoring, (ii) adoption of the open science approach, (iii) cooperation among the fragmented multi-level governance systems, (iv) knowledge co-production.

2.1.1 Criterion 1: Adoption of an agreed conceptual framework to monitoring

ECOAdS recognizes the need of an agreed conceptual framework for the harmonization of monitoring schemes, data acquisition and analysis at both national and trans-regional scales. ECOAdS embraces several observatory systems and monitoring frameworks, which target multiple environmental components presenting diverse approach and acting at different spatial and temporal scales. Among the main aims of ECOAdS there is the integration of all these existing monitoring programs into the N2K network ones, where these exist. This effort should be accompanied with the establishment of a set of selected and shared environmental monitoring variables, which have been indicated with the term descriptive indicators in deliverable 3.3.1 "Report on the key oceanographic processes and performance indicators for Natura 2000 marine sites", recognized for being adequate to describe globally the state of the marine environment, also coherently with the EU legislative requirements (see section 3.1). These latest are the starting point for ECOAdS implementation, since the observatory should answer to the monitoring requests of EU directives dealing with marine environment management and conservation, to help the achievement of their goals.
Besides, ECOAdS aims at integrating different but complementary conceptual schemes of environmental variables, for identifying drivers of biodiversity changes, such as the Ecosystem Integrity framework, adopted by the LTER communities (Haase et al., 2018), the Essential Biodiversity Variables (EBVs) (Pereira et al., 2013), developed by the Group on Earth Observations-Biodiversity Observation Network GEO-BON, and the Essential Ocean Variables (EOVs) (Miloslavich et al., 2018), implemented by the Global Ocean Observing System GOOS (see section 3.2).

2.1.2 Criterion 2: Adoption of the open science approach

Central to the development of ECOAdS, to inform properly the management and conservation of N2K and the marine environment, is the adoption of the open science approach. Open science practices and the application of the FAIR (Findable, Accessible, Interoperable, and Reusable; EC, 2016) principles in ecology has become increasingly necessary for responding to conservation issues and for addressing environmental changes, by removing the cultural, institutional and technological barriers through the establishment of open information flows. Indeed, such an approach allows the sharing of data and knowledge among scientists, decision-makers and citizens at local, national and transnational scales. Taking into account the experiences already available in the area (Menegon et al., 2018; Minelli et al., 2018; Acri et al., 2020; Minelli et al., *in press*) and the different levels of maturity in respect to open science, ECOAdS proposes tools and facilities to better disseminate the available data and information to diverse potential end-users (e.g. local, regional and national public authorities, managers of protected areas and N2K sites, education and research organizations). The aim is to implement an easily accessible web portal giving, whenever possible, open access to the data and observations collected by fixed-points systems and monitoring programs (see deliverables 5.2.1 and 5.3.1) in the area.

2.1.3 Criterion 3: Cooperation among the fragmented multi-level governance systems

The present EU status still reflects a fragmented approach in the conservation and management of N2K sites within the wider context of marine environment (see section 3.1). Data and information gathered and made available through ECOAdS should inform different policies and strategies, dealing with marine conservation, planning and management at both national and EU level, in particular the HD and BD, and the WFD and the MSFD. In addition, all EU countries, driven by legal commitment under the Maritime Spatial Planning Directive (EC, 2014; MSPD), are now developing their own marine spatial plans. More than usual it is a critical issue to inform this process in order to properly find space for new areas devoted to marine conservation, N2K sites included. ECOAdS can support a systematic conservation planning and the definition of marine areas of priority for conservation to support a coherent conservation network and to favour ecosystem-based management implementation (see Box 1).

By embracing existing and coming observatory systems and monitoring programs in the Adriatic region, which cover different spatial scales, from the more limited sites scale to the largest basin scale, ECOAdS will require a nested structure (Raakjaer et al., 2014). This will enable the collection of all relevant environmental data and information representatives of each N2K site and the surrounding marine environment, gathered through the diverse monitoring programs, and a coordinated approach to monitoring at diverse governance levels. Such structure will be key to support conservation objectives,

which need to be achieved at the country and regional level, although conservation measures need to be implemented at the N2K site level (Louette et al., 2011). In this way, ECOAdS will concretely help the harmonization of the national and EU policies and the coherent management and monitoring plans of both existing and future N2K sites, becoming a decision-support tools for governance representatives and management authorities of the N2K sites (see deliverable 3.5.1), able to deliver the necessary information to boost adaptation strategies and ecosystem-based approaches (Karpouzoglou et al., 2016; Mol, 2006).
ECOAdS functions also as a cooperation bridge between Italy and Croatia, overcoming local and national boundaries, representing the opportunity of removing geopolitical limitations to build a regional-based marine knowledge framework.

2.1.4 Criterion 4: Knowledge co-production

Human presence plays an important role and influence in the success of the N2K network, thus making it necessary to combine the social and ecological dimensions (Tsiafouli et al., 2013). During the ECOSS project diverse engagement events have been organized targeting different stakeholder groups (N2K sites managers, local authorities, researchers, students) to foster the building up of ECOAdS to embrace their expectations, needs and suggestions. Indeed, ECOAdS by favoring the application of an ecosystem-based approach to N2K sites management, aims at posing people in the condition both to be able to recognize their deep interconnection with nature, and to approach the existing knowledge related with the marine environment. In addition, ECOAdS recognizes the role of multiple knowledge sources to deal with uncertainties derived by knowledge gaps (Shabtay et al., 2019), by entailing local and traditional knowledge and directly engaging local communities that should become part of the observatory system itself (Blicharska et al., 2016). This participatory approach has been adopted to entail a bottom-up approach within ECOAdS that poses itself in the interface between scientists and non-experts, activating a multi-actors dialogue and engaging the civil society benefiting from N2K sites to incorporate local ecological knowledge (LEK), as well as involving the younger generation of scientists.
End-users and stakeholders engagement is at the heart of building and sustaining an observatory: it stimulates the increase in the ocean observing capacity, facilitate sharing of infrastructure, promote best practices, build capacity, foster diversity, and develop innovative technologies and approaches (Mol, 2006). Several experiences coming from both terrestrial and marine sites highlighted the added value

gathered when citizen science mechanisms are set up in monitoring approaches, through the adoption of voluntary sighting activity, questionnaires, interviews and interactive open access portals (Marocco et al., 2019; Mason et al., 2015; Sullivan et al., 2014). Although the citizen science approach is not yet a common practice in the implementation of the N2K network, there is empirical evidence of their usefulness for the enrichment of environmental monitoring databases and information frameworks (Kallimanis et al., 2017). ECOAdS, in this context of sharing knowledge and information, will favour the meeting among individuals, organizations, and agencies at multiple governance levels, as well as between these actors and the marine environment, thus supporting the operationalization of an ecosystem-based approach. The synergy between experts, the civil society and N2K managers, would support the governance and management systems of N2K network to effectively implement them in the Adriatic at multiple spatial scales and governance levels.

3. THE NEED TO HARMONIZE THE EXISTING MONITORING FRAMEWORKS

As highlighted in section 2, there is a strong need to harmonize the existing frameworks that deal with the monitoring and management of the marine environment in the Adriatic Sea, with special regard to N2K network. Since ECOAdS aims at favouring such harmonization, it must consider these frameworks and the synergies among them, as well as the potential limitations that can hinder their possible coordination both nationally and transnationally. The main monitoring schemes that can inform ECOAdS construction and development are here reported. Firstly, the Nature directives (HD and BD) and their state of implementation in Italy and Croatia are described in detail. Then, they are compared with the WFD and MSFD, bringing out their commonalities and discrepancies to orient the build of ECOAdS as a monitoring platform that may respond and contribute to their requirements, boosting the synergies and overcoming the weaknesses. Secondly, the EOV and EBV frameworks are considered and resumed since, as stated in section 2, they have been recognized as essential monitoring frameworks for achieving policy and sustainability goals at global scale. Finally, the monitoring programs detailed in deliverable 3.1.1 are summarized, being the primary source of long-term monitoring data that need to be entailed in ECOAdS.

3.1 Nature directives and comparison with WFD and MSFD

Starting from the Convention on Biological Diversity (CBD, 1992), several initiatives and legal commitments have been established by the EU to support the achievement of its main objectives at the level of all Member States (MS). These objectives foresaw (i) the conservation of biological diversity, (ii) the sustainable use of the components of biological diversity, and (iii) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. The EU recognized the priority of establishing legal instruments to address the conservation of habitats and species in all EU territory. The EU legislation has the power to set regulations and directives directly on the MS, which are obliged to transpose and implement them at the national level (Mackelworth et al., 2011).

The HD (92/43/EEC) and the BD (2009/157/EC) were the first legal instruments developed and enacted by the EU. The BD was first drafted in 1979 and amended several times, and here we refer to the last version, revised in 2009. These two directives together establish the need to build a coherent ecological network of protected sites, defined as Special Areas of Conservation (SACs) under the HD, and Special

BOX 1. ECOSYSTEM-BASED MANAGEMENT (EBM)

The Rio Declaration adopted at the United Nations Conference on the Human Environment and Development (UNCED) called upon States 'to conserve, protect and restore the health and integrity of the Earth's ecosystem' (Rio Declaration, principle 7, 1992). In that context, Agenda 21 was adopted, which concludes that oceans and adjacent coastal areas form 'an integrated whole that is an essential component of the global life-support system.' This realization requires 'new approaches to marine and coastal area management and development, at the national, sub-regional, regional and global levels, approaches that are integrated in content and are precautionary and anticipatory in ambit...' (Agenda 21,17.1, 1992) (UNEP/GPA, 2006). The implementation of an ecosystem-based management (EBM) , or ecosystem-based approach (EBA) often use interchangeably, was the answer. EBM recognizes that plant, animal and human communities are interdependent and interact with their physical environment to form distinct ecological units called ecosystems (UNEP/GPA, 2006), and that human welfare and health depends on ecosystems and the benefits they deliver. Since ecosystems are transboundary in character, typically cutting across existing political and jurisdictional boundaries and are subject to multiple management systems, EBM entails an integrated approach to management. EBM involves two changes in how management is practiced: (1) each human activity is managed in the context of all the ways it interacts with marine and coastal ecosystems, and (2) multiple activities are being managed for a common outcome. EBM is science-based, and answers to the knowledge gaps with the precautionary approach. EBM entailed 5 core principles (UNEP, 2011):

1. Recognizing connections within and across ecosystems;
2. Utilizing an ecosystem services perspective;
3. Addressing cumulative impacts;
4. Managing for multiple objectives;
5. Embracing change, learning, and adapting.

Protection Areas (SPAs) under the BD, to build what the EU calls Natura 2000 (N2K) network. The main aim of N2K network is to "promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements, making a contribution to sustainable development". The socio-economic dimension is relevant in the context of the N2K network, because it is recognized the importance of coastal and marine resources to support the development of the local communities economy. For this reason, the sustainable use of natural resources is one of the priority objectives together with the protection of biodiversity.

In Italy, the BD and HD have been transposed by the Government with the Framework Law 157/1992, and the DRP 357/1997, later modified with the DRP 120/2003, respectively. According to the Decree of the Republic President (DRP) n° 357/97, Regions and Autonomous Provinces are in charge of the establishment and implementation of all conservation measures to protect and monitor the N2K sites. They can also delegate other authorities (provinces, municipalities, local communities, management bodies of protected areas) to carry out the assessment of the existing conservation measures, the implementation of the management plan, the monitoring activities, and any other actions needed to ensure N2K site protection and effectiveness. In case a N2K site falls within another protected natural area, the managing authority of the protected area identifies conservation measures as part of its own regulation and planning instruments (D.3.3.1). If the N2K site falls partially within another protected natural area, DRP 357/1997 specifies "for the portion falling outside the perimeter of the protected natural area, the Region or autonomous Province shall adopt, after consultation with the relevant local bodies and the managing body of the protected area, all opportune conservation measures and management norms". Thus, the adoption and approval of the conservation measures always require the involvement of the regions and autonomous provinces, in collaboration with the State and local authorities.

In Croatia, the Nature Protection Act founded in 1960 the Nature Conservation Institute, to coordinate the environmental protection actions (Mackelworth et al., 2011). After the entry of Croatia into Europe, the Nature Protection Act and its additional emendations (Official Gazette OG 80/2013, 15/2018, 14/2019, 127/2019) entailed the requirements of HD and BD. Then, in 2002, the State Institute for Nature Protection (SINP) was created as a responsible institution for nature protection activities and the establishment of the N2K network (Šobot & Lukšič, 2016). As reported in Deliverable 3.2.1, in Croatia, according to the Nature Protection Act and OG 80/2019, N2K sites are managed by Public Institutions (PI), and a single PI can manage numerous sites contemporarily. When an N2K site is or overlaps a National Park, the responsible for the latter is also responsible for the N2K site. At the national level, the responsible authority for nature protection is the Ministry of Economy and Sustainable Development. This means that, if a N2K site is partially or entirely outside the Croatia territorial waters but within national jurisdiction, the Ministry of Economy and Sustainable Development is the responsible authority of the site. Management plans are mandatory for N2K sites and are adopted by the responsible authorities. Non-Governmental Organisations (NGOs) also play a fundamental role in protected areas implementation.

Despite the N2K network being the main instrument for nature protection in Europe, there are several limitations that weaken its conservation actions in the marine environment. The sites' selection by today has been mainly carried out without a real assessment of the conservation priorities, mainly by extending terrestrial sites at sea, establishing small and unrepresentative marine protected sites, leaving offshore and deep-sea habitats and species out from this network (Giakoumi et al., 2012, Mazaris et al., 2018, Manea et al., 2020). The absence of offshore N2K sites was recognized so far, and for this reason the Commission established an *ad hoc* working group that in 2007 published the guidelines for the establishment of N2K sites in the marine environment (EC, 2007). With this document, among the different guidelines provided, the Commission aimed at highlighting that different habitats and species were not covered by the HD and BD yet, and at stressing that the HD retains legal power also in the offshore areas beyond the territorial waters. Nonetheless, the limited extent of the N2K network in offshore waters still remains critical.

The issue of not covering all the habitats and species that deserve protection is also due to the limited numbers of marine habitats and species considered and listed within the annexes of the HD. However, addressing conservation objectives towards habitats instead of just species represents an attempt to protect a larger number of species, beyond the ones listed in the annexes (Evans, 2012). Nonetheless, many vulnerable species are still left outside the network and there is the need to update the annexes' lists (Maes et al., 2013).

One other important limitation to the network implementation is that most of the coastal and marine N2K sites seriously lack management strategies and related plans, a fact that hinders the concrete implementation of these sites and their operational effectiveness (Claudet et al., 2020). This is true in the Adriatic Sea, and in the seven N2K sites selected as case studies in the ECOSS project, as none of the sites possesses a management plan (see Deliverable 3.2.1 "Report on the ecological monitoring, conservation strategies and management questions of Natura 2000 marine sites”). Only the management body of the Po River Delta sites (IT3270017 and IT3270023) has produced its own management plan, but this is not yet enforced. The absence of a management plan have profound and serious implications such as: (i) the absence of precise and clear regulations that govern the sites and the activities that are here allowed and carried out, (ii) the lack of clarity about what conservation and management objectives have to be addressed and achieved at the site level, and (iii) even though some rules are set, a complete lack of effective programs for monitoring the respect of the existing restrictions and the state of the protected habitat and species.

The N2K network in the Adriatic must be enlarged beyond the N2K sites already present for the achievement of conservation targets established by the CBD and the Sustainable Development Goal 14 (SDG14) with respect to its Target 14.5 “By 2020, conserve at least 10 percent of coastal and marine areas, consistent with national and international law and based on the best available scientific information”. Furthermore, the worldwide marine conservation target has been proposed to increase up to 30% by 2030 (IUCN, 2014). Nowadays, efforts are being spent to identify new coastal and marine sites that deserve to be protected in the Adriatic (de Francesco et al. 2020), and one offshore N2K site, SIC IT3270025 “Adriatico Settentrionale Veneto - Delta del Po” is under implementation in Italy, in front of Veneto and Emilia-Romagna regions, with the goal of protecting bottlenose dolphins and sea turtles (DELIBERAZIONE DELLA GIUNTA REGIONALE n. 1135, 06 August 2020). The planned expansion of the N2K network represents a further element that recalls the need to make this instrument more operational and effective.

3.1.1 Interconnections and synergies among directives

An effective supporting strategy for improving the implementation of the Nature directives and of the N2K network is to take advantage and apply the numerous synergies that exist among the H&BD and the other environmental related directives that act on the aquatic environments, namely the WFD (2000/60/EC) and the MSFD (2008/56/EC). In Deliverable 3.3.1 it is reported a detailed analysis of the main synergies among these different legal instruments. We here summarized the main outcomes of such analysis.

Firstly, the H&BD, the WFD and the MSFD share the common goal of protecting the aquatic environments and their species, and of preserving and supporting the sustainable management of all the resources and benefits that these provide to humans by applying an ecosystem-based approach. To this respect, these regulatory instruments can be strongly complementary, perhaps partly overlapping, and if applied in a coordinated way they can support each other and increase their mutual effectiveness. The H&BD mainly focus on *in situ* conservation of specific target species and habitats. The wider approach of both the WFD and, especially, of the MSFD, which includes also functional aspects and the ecosystem as a conservation unit, can strongly contribute to the conservation efforts applied by the N2K network, leading to the possible overcoming of its diverse limitations, such as the unsatisfactory spatial extent and number of species under protection. Indeed, both the WFD and MSFD aim at achieving or maintaining a good quality status of diverse aquatic environments, and act at a large spatial scale, the WFD being focused on all internal and coastal waters - up to 1 nm - and the MSFD extending from the coastal to offshore areas. In addition, the MSFD aims at supporting the identification of new marine areas of priority for protection, thus representing a useful instrument supporting the process of N2K network extension, which is a critical step to take in the next future under the H&BD.
Then, both WFD and MSFD have been conceived as strategic instruments for setting up programmes for monitoring the environmental status: they can therefore provide a knowledge framework supporting those N2K sites that lack management plan and, as a consequence, monitoring strategy or dedicated funding to finance monitoring activities. Finally, the MSFD can help in establishing a management plan where these are missed, by orienting conservation measures starting from those developed under its own Programme of Measures (EC, 2018).

The main elements of comparison among the here considered directives are summarized in Table 2.

Table 2. Principal aspects related to the jurisdictional framework focused on environmental protection and the establishment of Protected Areas for the conservation of natural aquatic/marine ecosystems. The most relevant jurisdictional instruments in the framework of the ECOSS Project are compared. HD = Habitats Directive; BD = Birds Directive; WFD = Water Framework Directive; MSFD = Marine Strategy Framework Directive.

Comparison features	HD (92/43/EEC)	BD (2009/157/EC)	WFD (2000/60/EC)	MSFD (2008)	References
i) General objectives and target of protection	- Maintenance of biodiversity, taking account of economic, social, cultural and regional requirements, and making a contribution to the sustainable development. - Protection of selected species and habitats identified as of priority for protection. - Achievement or restoration of the Favourable Conservation Status (FCS).	- Maintain natural birds populations in the wild state to ecological-scientific-cultural adequate levels. - Protection of selected species and habitats identified as of priority for protection. - The preservation, maintenance or restoration of a sufficient birds diversity and area of habitats.	- Maintain and improve the quality of the aquatic environment in the Community. - Achievement of Good Ecological Status* (GEcS) of all waters by 2015, or 2021. - Achievement of the Good Chemical State (GCS) of all waters by 2015, or 2021.	- Protection and conservation of the marine environment, promotion of the sustainable use of the seas, and conservation marine ecosystems. - Achievement and maintenance of Good Environmental Status† (GEnS) of marine waters by 2020.	Directives; EEAC, 2018
ii) Approach to conservation	- Spatial and management measures mainly through the establishment of the EU ecological Natura 2000 Network of protected sites (Special Areas of Conservation – SACs). - Proactive and reactive: beyond conservation measures, it considers restoration and recovery actions. - They work more at national level even though regional	- Spatial and management measures mainly through the establishment of the EU ecological Natura 2000 Network of protected sites (Special Protection Areas - SPAs). - Proactive and reactive: beyond conservation measures, it considers restoration and recovery actions. - They work more at national level even though regional cooperation is highly recommended. - List of bird species and habitats to protect and monitor already defined.	- Ecological state including ecosystem functioning, beyond the protection of single species and habitats. - Deconstructing, structural approach§ , based on 5 biological quality elements (BQE) plus hydromorphological and physicochemical quality elements. - Proactive and reactive: beyond conservation measures, it considers restoration.	- Holistic, functional approach. - Proactive and reactive: beyond conservation measures, it considers restoration and recovery actions. - Explicitly ecosystem-based. - Highly transnational (needs to work through regional programmes). - Consideration of socio-economic aspects. - It explicitly includes ecological connectivity. - It integrates the precautionary approach.	Directives; Borja 2005; Allan *et al.*, 2006; Borja *et al.*, 2010; Mee *et al.*, 2008); FAQ final 2012-07-27; https://ec.europa.eu/environment/nature/natura2000/marine/docs/FAQ%20final%202012-07-27.pdf

	cooperation is highly recommended. - List of species and habitats to protect and monitor already defined.				
iii) Spatial application	- Broad. - 9 main biogeographic regions with representative habitats and species. - Transitional, coastal and territorial waters, including EEZ where declared. - *In situ* protection.	- Broad. - European territory and not biogeographic regions. - Transitional, coastal and territorial waters, including EEZ where declared.	- Rivers, lakes, transitional and coastal waters up to 1 nm from the coastline. - River basin districts as management units for River Basins Management Plans.	- Broad. - Marine regions that include sub-regions. - Coastal and territorial waters, including EEZ where declared.	Directives
iv) Reporting period	- Reporting every 6 years on the implementation of national provisions taken under the directive and their effectiveness. - Need of monitoring to "undertake surveillance of the conservation status of the natural habitats and species".	- Originally reporting every 3, later 6 years on the implementation of national provisions taken under the directive.	- Monitoring and reporting every 3 years.	- Monitoring and reporting every 6 years.	FAQ final 2012-07-27; Directives; Borja 2005
v) Human activities, derived pressures, and ecosystem services (ES)	- Mainly hunting, illegal killing, trapping and trade of species - In its objectives the directive entails considerations of economic, social, cultural and regional aspects rooted in the use of natural resources,	- Mainly hunting, illegal killing, trapping and trade of birds - Long-term protection and management of natural resources as an integral part of the heritage of the peoples of Europe. - Control natural resources and governs their use on the basis	- Member States should ensure a review of the impact of human activity on the status of surface waters and on groundwater - Mainly focuses on pollution sources and to reduce the discharge and emission of pollutants and hazardous substances - Clear reference to water provisioning as	- The strategy addresses all human activities that have an impact on the marine environment. - Human-derived pressures and impacts to monitor and manage specified and described (Annex III). - Reference to the adoption of an	Directives; https://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm; EU 2017/848

	making a contribution to the sustainable development. Not explicit reference to ES.	of the measures necessary for the maintenance and adjustment of the natural balances between species as far as is reasonably possible. Not explicit reference to ES.	fundamental service to human	ecosystem-based approach and to the importance of the marine environment for the services and benefits it delivers to humans.	
vi)Criteria and Performance indicator	- Criteria for site selection both for a given natural habitat and species, Annex III. - Achievement or restoration of the Favourable Conservation Status (FCS, Favourable, unfavourable - inadequate, unfavourable - bad, unknown) and associated criteria for both habitats and species.	- Not indicated explicitly in the directive. For selection of N2K sites for birds protection, the criteria are the same indicated in the HD. - Achievement or restoration of the Favourable Conservation Status (FCS, Favourable, unfavourable - inadequate, unfavourable - bad, unknown) and associated criteria for both habitats and species.	- Good Ecological Status (GEcS). - Good Chemical State of all waters. - High, good, moderate, poor, bad quality of the ecological status defined by normative.	- Good Environmental Status (GEnS). - 11 descriptors. - Good or not good.	Directives
vii) Indication for monitoring	- Required monitoring but not explicit indication. - Adoption of *parameters* for site selection and monitoring	- Required monitoring but not explicit indication. - Adoption of *parameters* for site selection and monitoring	- Detailed monitoring requirements (e.g. types of monitoring, monitoring frequency). - Adoption of *quality elements* to be monitored	- Detailed monitoring requirements. - Established criteria and methodological standards on Good Environmental Status (GEnS) and specifications and standardised methods for monitoring and assessment. - Adoption of *criteria* linked to the 11 descriptors to be monitored	Directives; EU 2017/848

*GEcS is defined as the values of the biological quality elements for the surface water body type which show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions.

†GEnS is defined as the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations.

§The approach has been defined as a "deconstructing structural approach" (Borja et al., 2010) since (i) it separates the ecosystems into several quality elements and districts, then (ii) it compares their structure individually and, finally, (iii) it combines them to assess the overall conditions.

Beyond the evident synergies that exist between the Nature directives and the WFD and MSFD, other policies can provide great benefits to the implementation of N2K network. From the comparative analysis carried out in Deliverable 3.3.1, it emerged that also the Common Fishery Policy (CFP, EU 2013) and the Maritime Spatial Planning Directive (MSPD, EC 2014) present important synergies with H&BD that deserve to be considered.

The CFP aims at conserving the marine resources related to the fishery sector, and to guide the sustainable management of the fishery activities. It defines the need to identify biological sensitive areas, marine areas closed to fishery, and recognizes the authority of Nature directives and the priority of managing not only professional fishery, but also the recreational one as well as the aquaculture sector, within the N2K network, considering the potential environmental pressures that might derive from them. Relevant synergies between the CFP and the implementation of the N2K network are evident, considering the ecology of many marine species that may present distinct foraging, breeding and spawning sites and/or a highly migratory nature. To protect them, the *in situ* approach, related to the single protected site, may not be enough and a broader approach to conservation through the application of sustainability fishery measures is essential. The monitoring programmes planned under CFP can therefore be beneficial to inform conservation initiatives and the efficacy of N2K sites in protecting nursery habitats of species of commercial value.

As for the MSPD, this directive imposes to MS to develop and enforce a maritime spatial plan in their own territorial waters by 2021. MSPD's main goal is to boost Blue Growth objectives (EC, 2012) considering the multisectoral reality of the maritime economy. Thus, this directive is not conceived as an instrument focalized on marine conservation needs. Nonetheless, the directive clearly asks for the application of an ecosystem-based approach along with the development of the maritime spatial plans. In addition, marine conservation tools are listed among the spatial instruments that are necessarily to be established and implemented, and the sustainable development of all human activities, by ensuring that the collective pressure of all activities is kept within levels compatible with the achievement of good environmental status, is highlighted as mandatory. Thus, MSPD is potentially of great help in making effective the expansion and implementation of the N2K network. It is at the moment on-going at the EU Commission level an animated debate on whether the Nature directives, as well as the WFD and MSFD, will be adopted by the MSPD as monitoring and knowledge base instruments for the maritime spatial plans implementation today and in the future cycles of the plans. Such an approach would be reasonable and recommended because it would likely enhance the level of effectiveness and synergy of all these legal instruments which could greatly benefit from each other.

3.2 The EBV and EOV frameworks

The Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs) are monitoring frameworks set up at the global level to answer to the need of monitoring the marine environment to detect variations in its state across time and space in response to natural, human and climate-induced factors, and to support the adaptive management of the marine resources to achieve high-level conservation and sustainability goals at both regional and global scales (e.g., CBD goals, IPBES, and SDGs; Bax et al., 2018).

The EOVs have been conceived in the framework of Global Ocean Observing System (GOOS) and are defined as “an interdisciplinary, feasible set of observations needed to characterize change and improve predictive skills for identifying and communicating ocean state and trend” (Lindstrom et al., 2012; Bax et al., 2018). Since 2013, IOC-GOOS has worked on defining EOVs to meet the need of delivering ocean data to support governance and management (Miloslavich et al., 2018). They consist of a variegated set of variables that includes physical, biogeochemical and biological components (Table 3). Their definition process is still ongoing especially for the identification of additional biological variables, as for instance marine microbes or genetic diversity, thus the list is continually updated with time and with the emerging of new science and technology advance (Bax et al., 2018).

Table 3. Essential Ocean Variables (EOVs) identified by the UNESCO/IOC Global Ocean Observing System. Source: Bax et al. 2018. *Emerging EOVs include Microbe biomass and diversity, and Benthic invertebrate abundance and distribution*

Physics	**Biogeochemistry**	**Biology and ecosystems**
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transients tracers	Marine turtle, bird and mammals abundance and distribution
Sea surface temperature	Particulate matter	Hard coral cover and composition
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Stable carbon isotopes	Macroalgal canopy
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity	Ocean color	
Subsurface salinity		
Ocean surface heat flux		

The biological EOVs depend on the measurement of a series of more specific sub-variables, many of which correspond to EBVs as defined by the Group on Earth Observations Biodiversity Observation Network (GEO BON) (Pereira et al., 2013).

The Essential Biodiversity Variables (EBVs) were proposed by the partners from the Group on Earth Observations Biodiversity Observation Network (GEO BON) as key variables to be considered in all monitoring programs worldwide. An EBV was defined as “a biological state variable that is measurable at particular points in time and space to document biodiversity change” (Schmeller et al., 2017). Thus, the EBVs have been conceived as those variables able to capture major changes of biodiversity at different biological levels (Pereira et al., 2013). The idea behind the EBV concept is that the key global biodiversity indicators that have been set to guide the achievement of the global biodiversity conservation goals lack of practicality from a monitoring perspective, not being able to act as up-to-date and early warning signals to assess biodiversity status and trends (Schmeller et al., 2018). A total of 22 candidate EBVs are proposed by GEO BON within six EBV classes (i.e. genetic composition, species populations, species traits, community composition, ecosystem functioning and ecosystem structure) (Pereira et al., 2013; Kissling et al., 2017; see Table 4).

Table 4. Essential Biodiversity Variables (EBVs) identified by the Group on Earth Observations Biodiversity Observation Network (GEO BON). Source: UNEP, 2013.

EBV class	Essential Biodiversity Variable
Genetic composition	Allelic diversity
	Co-ancestry
	Population genetic differentiation
	Breed and variety diversity
Species populations	Species distribution
	Population abundance
	Population structure by age/size class
Species traits	Phenology
	Body mass
	Natal dispersal distance
	Migratory behavior
	Demographic traits
	Physiological traits
Community composition	Taxonomic diversity
	Species interactions
Ecosystem structure	Habitat structure
	Ecosystem extent and fragmentation
	Ecosystem composition by functional type
Ecosystem function	Net primary productivity
	Secondary productivity
	Nutrient retention
	Disturbance regime

The EOV and EBV approach acts to inform and feed the high-level goals' indicators being at the interface between them and the raw data coming from the observations carried out within the most diverse monitoring programs that exist at different spatial scales and geographical locations.

Among the main challenges reported for EOV and EBV approach implementation there is the need to record data useful to build the framework in a systematic and comparable manner at multiple temporal and spatial scales (e.g., national, regional, global) using current technology and existing efforts (Kissling et al., 2015; Brummit et al., 2017; Bax et al., 2018). Indeed, any research or observation program, initiative and infrastructure can contribute to EOV and EBV development, independently by the scale on which it acts (Kissling et al., 2017). The other is technical, making sure that these data are going to be interoperable, otherwise they cannot be used to infer wider trends.

Despite EBV and EOV frameworks harness satellite systems utilization for large-scale data acquisition (Pereira et al., 2013), local and site related observations are important source of data, as the ones carried out in the Adriatic Sea through the monitoring programs entailed in ECOAdS, for downscaling ecological knowledge framework building. It is evident how fundamental is the application of a multiple scales approach to monitor in order to capture ecological and oceanographic characteristics of the marine environment and to track their changes in space and time and in response to global climate changes. For instance, as reported in Brummit et al. (2017), "in the case of the EBV 'Population Abundance' a species may have many different populations, each of which may be measured independently". Thus, the monitoring of the Adriatic population of bottlenose dolphin, *Tursiops truncatus*, for instance, can contribute to the EBV 'Population Abundance' related to marine mammals, as well as to the EOV 'Marine mammals abundance and distribution'. Thus, ECOAdS, acting as a collector of the multiple monitoring systems present in the Adriatic Sea, and favouring their harmonization, can help nourish the EBV and EOV frameworks.

4. ANALYSIS OF MONITORING VARIABLES: ZOOMING IN ON ECOAdS STARTING FROM ECOSS CONCEPTUAL MODEL

All the key elements that compose ECOAdS (Table 1) were linked together through the development of a conceptual model, which is thoroughly described in Deliverable 3.3.1. The idea behind the model is to include in a unique conceptual scheme the most important socio-ecological elements related to the management of N2K sites and to summarize their connections. Thus, the main aim of the model is to provide a visual tool to communicate with diverse targeted audiences (e.g., policy makers, Marine Protected Areas - MPA - managers, researchers, the civil society) about simplified cause-effect relationships among the considered elements, which are the ones that guide and support the effective

management of a marine protected area. Through a flow diagram, the model connects objectives, inputs, and results, and links the different phases and elements at the foundation of any management strategies addressed towards the implementation of areas of conservation, in order to provide a roadmap of information to orient future actions and ameliorations of the strategy in an adaptive way.
The ECOSS model highlights the key role of ECOAdS as the engine of this conceptual framework, which links the ecological and oceanographic dimensions with the conservation of the coastal and marine environment and its management. Indeed, ECOAdS acts as a collector of data and information related to the ecological and oceanographic characteristics of the Adriatic Sea. It gathers data linked to ecological and oceanographic variables that, in turn, feed a set of performance indicators. This latter allows the monitoring and assessment of the state of achievement of the established management and conservation objectives of the marine N2K sites studied in ECOSS. Briefly, the existing monitoring programmes, the ecological and oceanographic variables, and the performance indicators are all included in the ECOAdS red box (Fig. 3). Performance indicators constitute a cross-cutting element (orange box), since they can be obtained from single ecological or single oceanographic variables, combinations of multiple ecological or multiple oceanographic variables, or even combinations of one or several ecological variables with one or several oceanographic variables. The socio-economic, management and governance elements are reported within the yellow boxes, the ecological elements within the green ones, and the oceanographic elements within the blue ones.

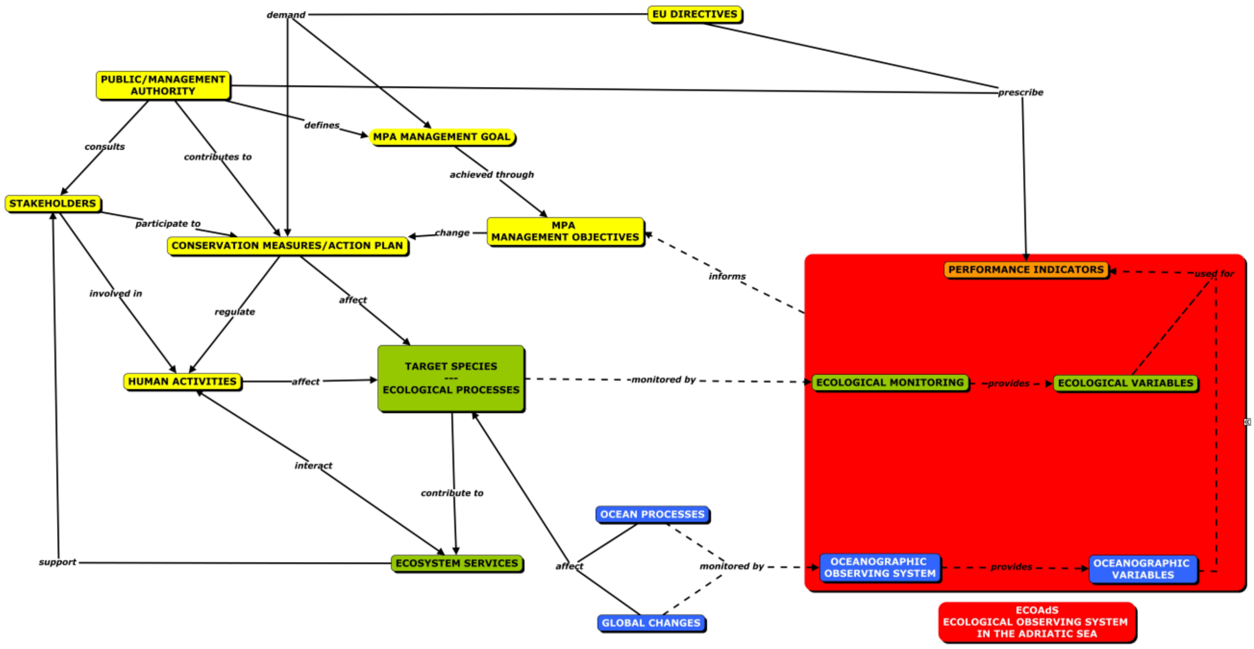

Fig. 3. Generic conceptual model linking ECOAdS with MPA management and EU Directives. ECOAdS is represented by the red box; the performance indicators are included in the orange box; the oceanographic elements are included in the blue boxes; the ecological elements are included in the green boxes; the socio-economic, management and governance related elements are included in the yellow boxes.

Here, we zoomed in on ECOAdS (red box) by analysing how it can link the ecological and oceanographic dimensions with the conservation goals and objectives of a MPA. Indeed, acting as a collector of different ecological and oceanographic monitoring systems and programs (Manea et al., 2020), ECOAdS can build up a complete picture of the state of the marine environment both within the MPAs, if monitoring activity is carried out, and outside areas of conservation at the Adriatic basin scale. To ensure the effectiveness of such an integrated approach to monitor, it is firstly necessary to harmonize the set of descriptive monitoring indicators (i.e., ecological and oceanographic variables) adopted. Indeed, the data collected through monitoring activities must be coherent and comparable to be integrated into a representative and complete knowledge framework related to the marine environment, and to support the construction of long-time series of data (Bax et al., 2018).

4.1 Directives' monitoring variables

Among the monitoring programmes embraced by ECOAdS, those linked to the fulfilment of the European directives' obligations are included as they prescribe the monitoring of their objectives and performance indicators (Fig. 4).

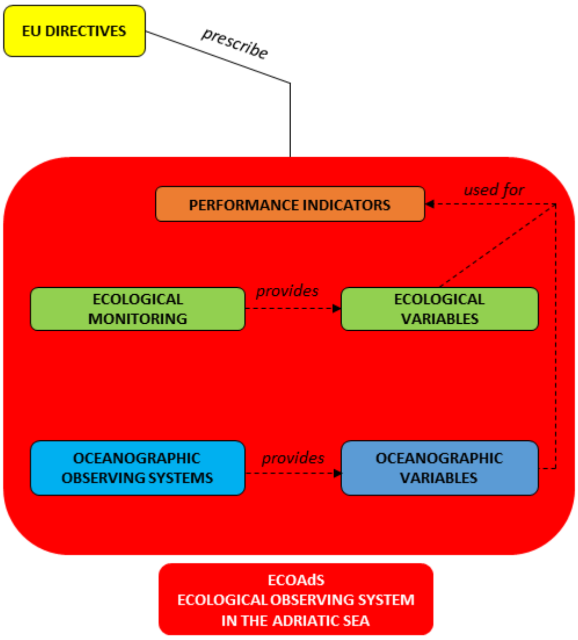

Fig. 4. EU Directives linked to ECOAdS within the conceptual model.

In particular, we referred to the four directives that have been compared in section 2, (H&BD, WFD and MSFD). In order to implement these legal instruments, the setting up of monitoring programs is required

for the achievement of their stated objectives. These programs are important sources of data and observations that, as emerged from their comparative analysis, cross diverse aquatic domains, from transitional waters to the offshore. Nonetheless, as described in section 2 and in deliverable 3.3.1, the directives do not deliver homogeneous guidance on how to monitor the N2K sites conservation targets and, more generally, the marine environment. This fact is an issue that can hinder an effective integration of the diverse monitoring efforts, leading to the loss of important and complementary information that can support a coherent and complete monitoring of the marine environment and N2K sites.
The four directives present diverse but complementary performance indicators, as highlighted in deliverable 3.3.1. As for the HD, the Favourable Conservation Status (FCS) can be regarded as performance indicator. Despite the BD does not explicit a performance indicator, the FCS can be applied for those bird species that enter in the HD Annexes list. The Good Ecological Status (GEcS) and the Good Chemical Status (GCS) are used as environmental indicators of system performance by the WFD, since they show the distance between the current state and the desired one of the defined quality elements that are subjected to monitoring. The MSFD set what we might consider as an overall performance indicator, the Good Environmental Status (GEnS), which is determined on the basis of eleven qualitative descriptors (Annex I; Table 5).

Table 5. List of the eleven Marine Strategy Framework Directive (MSFD) descriptors (Annex I, EC 2008).

Descriptor 1.	Biodiversity is maintained
Descriptor 2.	Non-indigenous species do not adversely alter the ecosystem
Descriptor 3.	The population of commercial fish species is healthy
Descriptor 4.	Elements of food webs ensure long-term abundance and reproduction
Descriptor 5.	Eutrophication is minimised
Descriptor 6.	The sea floor integrity ensures functioning of the ecosystem
Descriptor 7.	Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
Descriptor 8.	Concentrations of contaminants give no effects
Descriptor 9.	Contaminants in seafood are below safe levels
Descriptor 10.	Marine litter does not cause harm
Descriptor 11.	Introduction of energy (including underwater noise) does not adversely

The monitoring variables listed in these four directives and established to monitor the achievement of their performance indicators are expressed with different terminologies. Indeed, the H&BD refer to *parameters*, the WFD adopts *quality elements*, while the MSFD used *criteria*. For this reason, as a first contribution, ECOAdS made a first attempt to harmonize the monitoring approaches of these policy instruments, starting from the terminology adopted to guide them towards the achievement of their conservation and management objectives. Here below, Tables 6-9 report the analysis of harmonization carried out and described in detail in deliverable 3.3.1.

Table 6. Monitoring variables - *criteria* - of the MSFD with related criteria codes (EU 2017/848). Each criterion is linked to one MSFD descriptor.

Criteria Code	MSFD monitoring variables: Criteria
D1C1	Mortality rate from incidental by-catch
D1C2	Population abundance
D1C3	Population demographic characteristics
D1C4	Population distributional range and pattern
D1C5	Habitat for the species
D1C6	Pelagic habitat condition
D2C1	Newly-introduced NIS
D2C2	Established NIS
D2C3	Adverse effects of NIS
D3C1	Fishing mortality rate (F)
D3C2	Spawning stock biomass (SSB)

D3C3	Population age/size distribution
D4C1	Trophic guild species diversity
D4C2	Abundance across trophic guilds
D4C3	Trophic guild size distribution
D4C4	Trophic guild productivity
D5C1	Nutrient concentrations
D5C2	Chlorophyll a concentrations
D5C3	The number, spatial extent and duration of harmful algal bloom events
D5C4	The photic limit (transparency)
D5C5	The concentration of dissolved oxygen
D5C6	The abundance of opportunistic macroalgae
D5C7	The species composition and relative abundance or depth distribution of macrophyte communities
D5C8	The species composition and relative abundance of macrofaunal communities
D6C1	Spatial extent and distribution of physical loss (permanent change)
D6C2	Spatial extent and distribution of physical disturbance pressures
D6C3	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance
D6C4	Benthic habitat extent (loss)
D6C5	Benthic habitat condition (extent of adverse effects including alteration to its biotic and abiotic structures and its functions)
D7C1	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column

D7C2	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions.
D8C1	Concentrations of contaminants
D8C2	Health of species and the condition of habitats
D8C3	Spatial extent and duration of significant acute pollution events
D8C4	Effects of significant acute pollution events on the health of species and on the condition of habitats
D9C1	The level of contaminants in edible tissues of seafood
D10C1	The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed
D10C2	The composition, amount and spatial distribution of micro-litter on the coastline, in the surface layer of the water column, and in seabed sediment
D10C3	The amount of litter and micro-litter ingested by marine animals
D10C4	The number of individuals of each species which are adversely affected due to litter, such as by entanglement, other types of injury or mortality, or health effects.
D11C1	Spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources
D11C2	Spatial distribution, temporal extent, and levels of anthropogenic continuous low-frequency sound

Table 7. Monitoring variables - *quality elements* - of the WFD (Annex V; EC 2003) and associated criteria code of the MSFD. Notice that not all quality elements correspond to a MSFD criterion.

WFD monitoring variables: Biological quality elements (BQE), hydromorphological and chemical and physico-chemical quality elements supporting BQE	**Related MSFD Criteria Code**
Composition of aquatic flora (macrophyte)	D5C7

Abundance of aquatic flora (macrophyte)	
Presence of sensitive taxa of flora (macrophyte)	
Abundance of phytobenthos	-
Composition of phytobenthos	
Presence of sensitive taxa of phytobenthos	
Abundance of phytoplankton	D4C4, D5C2, D5C3
Composition of phytoplankton	
Bloom frequency of phytoplankton	
Bloom intensity of phytoplankton	
Biomass of phytoplankton	
Composition of benthic invertebrate fauna	D6C5, D1C2, D1C3, D1C4
Abundance of benthic invertebrate fauna	
Presence of sensitive taxa of invertebrate fauna	
Diversity of invertebrate fauna	-
Composition of fish fauna	D3C2, D3C3, D1C2, D1C4, D1C6, D1C3
Abundance of fish fauna	
Age structure of fish fauna	
Life cycle of fish fauna	
Presence of sensitive taxa of fish	
Historical flow	-
Modelled flow	-

Real time flow	-
Water table height	-
Surface water discharge	-
Number and type of barriers	-
Provision for passage of aquatic organisms	-
River cross section	-
Flow	-
Cross sections	-
Particle size	D6C5
Presence of Catchment Water Drainage	-
Location of Catchment Water Drainage	-
Length of the riparian zone	-
Width of the riparian zone	-
Species composition of the riparian zone	-
Continuity of the riparian zone	-
Ground cover of the riparian zone	-
Temperature	D1C6, D5C4, D7C1
Dissolved oxygen	D5C5, D6C3, D6C5, D7C2
Electrical conductivity	D5C4, D7C1, D1C6
pH	D1C6, D5C1, D5C5
Alcalinity	-

<table>
<tr><td>Acid Neutralizing Capacity (ANC)</td><td>-</td></tr>
<tr><td>Total phosphorus</td><td>D5C1, D1C6, D5C5</td></tr>
<tr><td>Soluble reactive phosphorus</td><td>D5C1, D1C6, D5C5</td></tr>
<tr><td>Total nitrogen</td><td>D5C1, D1C6, D5C5</td></tr>
<tr><td>Nitrate + nitrite</td><td>-</td></tr>
<tr><td>Ammonium</td><td>-</td></tr>
<tr><td>Suspended solids</td><td>-</td></tr>
<tr><td>Turbidity</td><td>D1C6, D5C4, D7C1</td></tr>
<tr><td>Pollution by all priority substances identified as being discharged into the body of water</td><td rowspan="2">D8C1, D8C3</td></tr>
<tr><td>Pollution by other substances identified as being discharged in significant quantities into the body of water</td></tr>
<tr><td>Composition of other aquatic flora (macrophyte)</td><td rowspan="2">D5C7</td></tr>
<tr><td>Abundance of other aquatic flora (macrophyte)</td></tr>
<tr><td>Mixing patterns</td><td rowspan="2">-</td></tr>
<tr><td>Circulation patterns</td></tr>
<tr><td>Inflow</td><td>-</td></tr>
<tr><td>Outflow</td><td>-</td></tr>
<tr><td>Lake surface</td><td>-</td></tr>
<tr><td>Lake volume</td><td>-</td></tr>
<tr><td>Lake depth</td><td>-</td></tr>
<tr><td>Water content of the lake bed</td><td>-</td></tr>
</table>

Particle size of the lake bed	-
Elemental composition of the lake bed	-
Sedimentation age of the lake bed	-
Sedimentation rate of the lake bed	-
Length of the lake shore	-
Species composition of the riparian zone	-
Vegetation cover	D5C7
Bank features	-
Secchi depth	D5C4, D7C1, D1C6
Colour	-
Total Organic Carbon (TOC)	-
Presence/absence of invertebrate fauna	D6C5, D1C2, D1C3, D1C4
Bioaccumulation	D9C1
Bioassay	-
Freshwater inputs	D7C1
Residence time	
Exchange	-
Wave exposure	-
Basin shape	-
Particle size of the bed	D6C5, D6C3, D5C5, D7C2
Organic content of the bed	

Vegetation composition of the tidal zone	-
Vegetation cover of the tidal zone	-
Diversity of phytoplankton	-
Diversity of other aquatic flora (Macrophyte)	D5C7
Presence of sensitive taxa of macroalgae	-
Depth cover of macroalgae	-
Distribution cover of macroalgae	D5C7
Diversity of angiosperms	D5C7
Abundance of angiosperms	
Presence of sensitive taxa of angiosperms	
Depth cover of angiosperms	
Distribution cover of angiosperms	
Biomass of invertebrate fauna	D5C8, D1C6, D1C4
Tide speed	-
Tide direction	-
Wave speed	D1C6, D7C1
Wave direction	
Freshwater flow	D7C1
Hydrological budget	-
Topography	-
Particle size of the coastal bed	-

Solid rock of the coastal bed	-
General characteristics of the coastal bed	-
Particle size of the intertidal zone	-
Solid rock of the intertidal zone	-

Table 8. Monitoring variables - *parameters* - of the HD (EC, 2012) and associated criteria code of the MSFD. Notice that not all parameters correspond to a MSFD criterion.

HD monitoring variables: Parameters	Related MSFD Criteria Code
Natural range of natural habitat types of community interest	D1C5
Area covered by natural habitat types of community interest	
Specific structure of natural habitat types of community interest	
Necessary functions of natural habitat types of community interest	-
Status of conservation of species in natural habitat types of community interest	D8C2
Population dynamics of animal and plant species of community interest	D1C2, D1C3, D1C4
Natural range of animal and plant species of community interest	D1C4
Presence of habitat for animal and plant species of community interest	D1C5
Population dynamics of animal and plant species of community interest in need of strict protection	D1C2, D1C3, D1C4
Natural range of animal and plant species of community interest in need of strict protection	D1C4
Presence of (sufficiently large) habitat of animal and plant species of community interest in need of strict protection	D1C5
Incidental capture and killing of animals of community interest in need of strict protection	D10C4

Presence of (sufficiently large) habitat of animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures	D1C5

Table 9. Monitoring variables – *parameters* - of the BD (EU 2012) and associated criteria code of the MSFD. Notice that not all parameters correspond to a MSFD criterion.

BD monitoring variables: Parameters	Related MSFD Criteria Code
Trends and variations in population for the species birds in the Annex I	D1C2, D1C3, D1C4
Trends and variations in population for species in danger of extinction	
Trends and variations in population for vulnerable species	
Trends and variations in population for species considered rare	
Trends and variations in population for other species requiring particular attention	
Trends and variations in population for migratory species not listed in the Annex I	
National lists of species in danger of extinction	-
Listing and ecological description of areas important to migratory species	
Listing population levels of migratory species as shown by ringing	
Role of certain species as indicators of pollution	
Adverse effect of chemical pollution on population levels of bird species	D8C4

As ECOAdS aims at integrating the ecological and oceanographic research and monitoring with the N2K conservation strategies, we addressed the matching of directives' monitoring variables with those emerged as being of priority to monitor the target species and habitats under protection within the N2K case study sites of ECOSS. These monitoring variables were selected in deliverable 3.3.1 on the base of

their relevance because able to depict the state of each conservation feature and to reflect the ecological processes that affect them, thus being faithful to the ecological connectivity concept.
In the current document, these variables were defined as ecological, oceanographic and of pressure, and were compared with those from the WFD and MSFD, the two main policy instruments for aquatic environment monitoring. This comparison led to a further terminology harmonization and to the identification of which among the N2K sites-related variables are already considered in the directives' monitoring frameworks. This harmonization is critical to avoid that the same monitoring variables are defined differently by diverse monitoring programs in a way that the derived data are of quality and can be integrated and compared among them, which is an essential prerequisite to build a comprehensive and coherent knowledge framework on the state of any species or habitat (Lopez y Royo et al., 2010). The variables belonging to the EOV and EBV frameworks were also considered in this harmonization analysis. Indeed, an additional aim was to test the possible contribution that ECOAdS may give to these global frameworks through the integration of the existing and potential local monitoring programs. At the same time, such comparison might be of value to inform EOV and EBV frameworks building.
In Annex I, tables A1-A30 show the results of the harmonization analysis.

4.2 Link to the N2K case study sites and to the existing monitoring programs

Among the monitoring programmes embraced by ECOAdS, of paramount importance are the ones that already exist in the area and that provide part of the oceanographic and ecological variables needed to inform the performance indicators and MPAs management (Fig. 5).

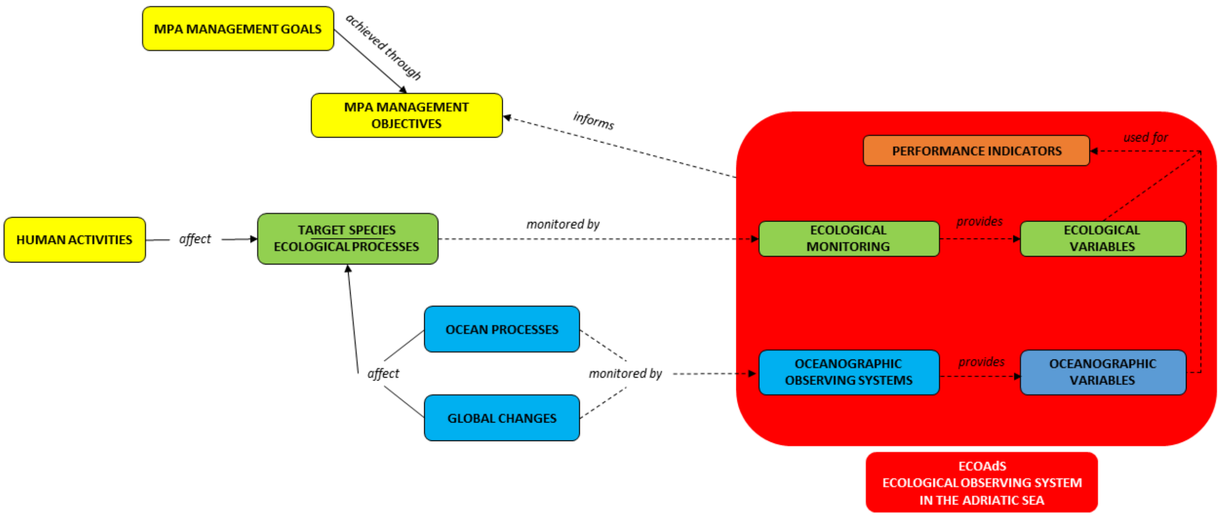

Fig. 5. Existing ecological monitoring and oceanographic observing systems integrated in ECOAdS within the conceptual model.

Here, in Table 5 we report the monitoring programs that exist in the area and which the ECOSS partners are responsible of, considering their temporal and spatial aspects, as well as the institution responsible of the monitoring activity. Detailed information on the programs and on the monitored parameters is specified in deliverable 3.1.1. It has to be reminded that these programmes are not set up for monitoring N2K sites, even though they collect information relevant for their management. The variables - ecological, oceanographic and of pressure - monitored at each N2K sites (among the ones selected in deliverable 3.3.1) are listed in Annex II Table 1-3 and they refer specifically to the monitoring of target species and habitats. The tables are the results of direct interviews to the partners of the project, which are reference persons for the six N2K considered as case studies.

Table 5. Existing monitoring programs in the Adriatic, as detected within ECOSS. See also D3.1.1

Monitoring program	Temporal aspect	Spatial aspect	Monitored variables	Related directives	Responsible of monitoring activity
MSFD Croatia	6 years reporting	5 marine reporting units	Ecological, of pressure and oceanographic	MSFD and WFD (for coastal data only)	Institute of Oceanography and Fisheries, Split; Institute Ruđer Bošković, Zagreb
WFD Croatia	2 years	25 transitional water bodies, 26 coastal water bodies	Ecological, of pressure and oceanographic	WFD	Institute of Oceanography and Fisheries, Split; Institute Ruđer Bošković, Zagreb; National Laboratory of Health, Environment and Food, Maribor, Slovenia
Adriatic Dolphin Project	Year-round	Alongshore from Istria to Lastovo, extending to a few miles SW of the outer stretch of islands	Ecological and of pressure (underwater noise)	HD, MSFD	Blue World Institute
Sea turtles	Aerial surveys every 3 years	Whole Adriatic Sea	Ecological	HD, MSFD	Blue World Institute, Croatian Natural History Museum
LTER	Monthly to bimonthly	Northern Adriatic Sea, from the Gulfs of Trieste and Venice to the Delta del Po and Romagna Coast and to the area off-shore Senigallia	Ecological and oceanographic	WFD, MSFD	CNR-ISMAR, CNR-IRBIM, OGS and UNIVPM

Regional water protection plan	Monthly for physical parameters, nutrients, and contaminants in water; yearly for contaminants in sediment; every two months for biological parameters.	Gulf of Trieste (from Muggia to the mouth of Tagliamento river) - physical parameters: in 53 sampling stations (only 39 active stations at present); nutrients: in 21 sampling stations; contaminants in water: in 22 sampling stations; contaminants in sediment: in 19 sampling stations. All stations are included in 19 marine water bodies.	Ecological and oceanographic	MSFD	ARPA FVG
Water and shellfish in farms ARPA FVG	Microbiological analyses every two or three months; toxicological analyses every 15 days, two, three or six months; chemical analyses every three or six months	Gulf of Trieste, 52 sampling stations	Ecological and of pressure	MSFD	ARPA FVG, laboratories of the Experimental Zooprophylactic Institute of Venezie in Pordenone and Padua, Integrated University Health Agency of Trieste (ASUITs)
Bathing waters quality	Monthly from 1st May to 30th September every year	Gulf of Trieste, 55 sampling stations along the coast	Ecological and oceanographic	MSFD, WFD	ARPA FVG

Visual census of the seafloor by ROV	Yearly	Gulf of Trieste, in three areas (one area designed to study Maerl habitat and two areas to study human impacts on the seafloor). Every area has three sampling stations.	Ecological and of pressure	MSFD	ARPA FVG and Veneto regions
Seagrasses/macroalgae	Since 2000	Gulf of Trieste	Ecological and oceanographic	MSFD, HD	UNITS, OGS and FVG Region
Coralligenous monitoring-TRECORALA	Research project with defined time period (2012-2014)	Gulf of Trieste	Ecological	MSFD, HD	UNITS, OGS
Coralligenous monitoring-TETRAMARA	Research project with defined time period (2020-2022)	Gulf of Trieste and of Venice	Ecological	MSFD, HD	OGS, CNR ISMAR
Monitoring transitional waters (legislative decree n. 152/2006)	Specified in the report, depending on the parameter	Coastal lagoons of Caleri, Marinetta, Vallona, Barbamarco, Canarin, Scardovari; Mouths of Po river (Po di Maistra, Po di Pila, Po di Tolle, Po di Gnocca, Po di Goro).	Ecological and oceanographic	MSFD, HD, WFD	ARPAV, SISTEMI TERRITORIALI SPA
ARPAE monitoring program	Since 1981	Emilia Romagna coast, Sacca di Goro (MRU: no)	Ecological and oceanographic	WFD, MSFD	Daphne, ARPA Emilia-Romagna
Existing ecological monitoring observing systems (i.e. buoys, pylons, platforms)	Biological and chemical measurements are routinely acquired, with periodic sampling of the water column	5 stations, Northern Adriatic Sea	Ecological and oceanographic	WFD, MSFD	CNR-IRBIM, CNR-ISMAR, OGS, UNIVPM

5. A COHERENT ECOSYSTEM-BASED INDICATORS SYSTEM

We aimed at building a baseline of information to guide the definition of main gaps and challenges to overcome and address through the development of a coherent ecosystem-based indicator system, able to communicate with different monitoring frameworks, to inform policy objectives and to guide an EBM of N2K network. Firstly, as mentioned in section 4.1, the monitoring variables belonging to the diverse monitoring frameworks, up to here analyzed, were aligned to allow comparison and definition of possible correlations among them, based on the terminologies adopted and on the concept that lags behind them. We then linked the variables identified in deliverable 3.3.1 as of priority to be monitored in each N2K site - grouped in ecological, oceanographic and of pressure - to the large monitoring frameworks established and under development on large spatial scales (EU directives and EBV and EOV), to support the multi-scale and adaptive approach entailed within EBM in the Adriatic Sea and at N2K sites (see Box 2 for Adaptive approach to management definition). We also aimed at bridging the gap between the EOV and EBV frameworks and the EU environmental directives. Indeed, until today, these have proceeded on separate tracks, but since these global variables frameworks work on informing relevant policies at the regional level, we do consider relevant the matching among them. This exercise was useful also to test the level of applicability of the EOV and EBV frameworks at the level of the Adriatic N2K sites and basin.

In this paragraph, we gave a score to the ecological and pressure variables of priority to monitor selected target species and habitats, i.e., *Tursiops truncatus*, seagrass meadows, and *Pinna nobilis.* Studies related to these species have been carried out for a long time and today a good knowledge framework that can support the test to our approach is available. They are all present in the ECOSS N2K case study sites: the *Tursiops truncatus* in Cres Losinj, Viski akvatori, San Pietro e Bardelli, and Tegnue di Chioggia; seagrass meadows in Malonstonski zaljev and Parco Delta del Po; *Pinna nobilis* in Malonstonski zaljev, Trezze San Pietro e Bardelli, and Tegnue di Chioggia. The scores were given on the base of criteria adapted from Schmeller et al. (2018), to guide and test a prioritization approach to inform the definition of a possible ecosystem-based indicators system. The criteria are the following: (i) Policy relevance, (ii) Sensitivity to change, (iii) Feasibility, (iv) Potential involvement of citizens in data collection, (v) Representative (potential proxy) of ecosystem services availability. The system of monitoring variables and the selected criteria, indeed, entail the core principles of EBM (see Box 1). The variables come from deliverable 3.3.1 (see also Annex II) where they were selected to answer to the need of considering the ecological connectivity concept and the interconnections among species and species and the environment (EBM principle 1. *Recognizing connections within and across ecosystems*) in monitoring practices, as well as potential impacts affecting the target species and habitats (EBM principle 3. *Addressing cumulative impacts*). Potential source of impacts support EBM principle 4 as well (i.e. *Managing for multiple objectives*), since their monitoring informs N2K sites' management plans, which aim at balancing the achievement of both socio-economic and conservation objectives. The ecosystem services perspective

BOX 2. ADAPTIVE APPROACH TO MANAGEMENT

Adaptive management is an approach to policy implementation in which ecological responses to management actions are monitored and compared with respect to expected outcomes. This allows detecting differences between observations and expectations, thus guiding modifications to management in an iterative process (Walters, 1986; Armitage et al., 2008). The adaptive approach to management is at the base of sustainability implementation (Barnard and Elliot, 2015). It is also one of the core principles of EBM "Embracing change, learning, and adapting" (UNEP, 2011). Indeed, adaptive management is the approach that helps to define how to improve management strategies and actions (Douver and Ehler, 2010; Stelzenmüller et al., 2015; Varjopuro, 2019). It is at the core of conservation and spatial planning, since it allows to incorporate changes in time and space, in relation to both the human and environmental dimensions (e.g., changes in socio-economic needs and priorities, changes in environmental conditions due to human and climate-induced changes), as well as to evaluate MPA and protection measures effectiveness (Nickols et al., 2019). Monitoring is at the base of adaptive management, since the observing initiatives and the data and information they gather represent the critical components that can feed adaptations in management strategies.

(EBM principle 2) is adopted through the scoring criterion "*potential proxy of ecosystem services availability*", while EBM principle 5. *Embracing change, learning, and adapting* is entailed through the criterion "*sensitivity to change*", which allows to set up both an early warning monitoring approach to changes and an adaptive management. The criterion "*potential involvement of citizens in data collection"* allows also adopting the participatory and learning approach supported by EBM.

Here below, the criteria adopted to evaluate suitability and priority level of the monitoring descriptive variables (adapted from Schmeller et al., 2018) are reported. The criteria were selected and modified to make them suitable for the context of the N2K case study sites and on the basis of the characteristics of the monitoring variables analyzed.

i) Policy relevance = variable that belongs to or falls within the list of descriptive indicators of the directives and/or contributes to the EOV or EBV frameworks.

Scoring modality: 0 - None of these frameworks; + - at least one of the frameworks; ++ - at least one directive among WFD and MSFD plus EOV and/or EBV frameworks, or both the directives; +++ - both the directives, WFD and MSFD, and EOV and/or EBV frameworks.

ii) Sensitivity to change = variable able to communicate changes. The score given to this criterion is influenced by the ability of those who carry out the monitoring activity both to monitor the variables and to capture the information they provide.

Scoring modality: 0 - no changes can be detected; + - variable that takes 10 or more years to show change; ++ - variable that reveals change within 9 years; +++ - variable detecting change in less than 2 years.

iii) Feasibility = it depends on the presence of established monitoring methods, the effort in terms of the collection of samples to analyze and of time dedicated to the monitoring activity, and the monitoring cost-effectiveness.

Scoring modality: 0 - Not feasible; + - there is a scientifically proven method, but it requires great effort and it is not cost-effective; ++ - there is a scientifically proven method, no great effort is required, but it is not cost-effective, or the contrary; +++ - there is a scientifically proven method, no great effort is required, and normal resource use (human and financial) are sufficient.

iv) Potential involvement of citizens in data collection.
Scoring modality: 0 - NO; 1 - YES.

v) Representative (potential proxy) of ecosystem services availability. We here referred to the TEEB (2010) framework as reported in deliverable 3.4.1 "Report on the ecosystem services to be used for monitoring ecological processes within the Natura 2000 sites". This criterion was adopted only for ecological and oceanographic variables, as no pressure variables were considered appropriate for ecosystem services provisioning.
Scoring modality: 0 - NO; 1 - YES.

For each variable, we assessed also the presence or absence of long term series of data, coming from past monitoring programs or from existing observing systems in each N2K site for each monitoring variable (see Annex II).

5.1 *Tursiops truncatus*

The *Tursiops truncatus*, common bottlenose dolphin, is the only cetacean species regularly inhabiting the northern and central Adriatic Sea. Aerial survey campaigns conducted in 2010 and 2013 revealed three areas within the Adriatic with higher density of individuals: the northern Adriatic, the Jabuka pit and the southern Adriatic. In addition, diverse subpopulations of this species have been detected in the basin trough morphological and genetic studies. The species is characterized by long life span (40 to 50 years on average) and low reproductive rate. Historical records indicate that the Adriatic population of this species declined by 50% in the second half of 20th century, mainly due to voluntary killing by fishermen and to habitat degradation and prey depletion for excessive fishery pressure (Bearzi et al. 2009). Detailed information on the species is available in deliverable 4.2.1 "Review of the knowledge of the target species at the selected Natura 2000 sites".
The scores assigned to the ecological variables selected to monitor *T. truncatus* and the information related to their actual monitoring are reported in tables 6 and 7.

The ecological variables (table 6) presenting more relevance from a policy perspective to monitor *T. truncatus* are many, despite the WFD does not reflect on this species, which lives in marine waters, mainly offshore. Nonetheless, the dolphin behaviour metrics are not considered by the directives, despite they were found to be ones of the most sensitive to changes. Indeed, common bottlenose dolphins have been recognized as animals able to adopt different behaviour depending on the characteristics and geography of the area, the trophic niche occupied and the season, being highly adaptable and opportunistic (Bearzi et al. 2009). Thanks to the level of knowledge that have been built up today on this species, it might be possible to gather early warning signals of its state in case of anomalies on their behaviour. On the contrary, the ecological and pressure variable "birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats" found match with a MSFD descriptive indicator. However, the scores of this variable were the lowest, mainly because of the difficulty in monitoring it, since carcasses usually sink and for this reason are not visible, and by-catch in trawl nets is difficult to estimate from dead and stranded individuals (Bearzi et al., 2009). Sex ratio and age structure were also variables that fall in the list of the MSFD, as well as of the EBV and EOV frameworks. Nonetheless, they did gather lower scores, due to the possible difficulty in appreciating their variations for environmental changes and human pressures with time, and because of the impossibility of engaging citizens in their monitoring, as well as of the poor practicality in using such data for ES assessment.
The spatial distribution on the contrary is a sensitive variable to changes, followed by density and abundance, which are strictly interlinked. Such variables are all important since they can be used to feed habitat suitability models, which are relevant tools for extensive habitat mapping able to support management and conservation purposes even at large spatial scales (Bearzi et al. 2021, Bonizzoni et al. 2021).

Table 6. Score assigned to the ecological variables selected to monitor *T. truncatus* and information related to their actual monitoring.

Ecological variables to monitor *Tursiops truncatus*	Policy relevance	Sensitivity to change	Feasibility	Potential for citizens involvement	Proxy for ecosystem services assessment	Data availability in Cres Losinj	Data availability in Viski akvatori	Data availability in Trezze San Pietro e Bardelli	Data availability in Tegnue di Chioggia
Density	+	++	++	0	+	YES	YES	n.a.	YES
Abundance	++	++	++	+	+	YES	YES	n.a.	YES

Sex	++	0	++	0	0	YES	YES	n.a.	n.a.
Age	++	0	++	0	0	YES	YES	n.a.	n.a.
Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	++	0	0	0	0	NO	NO	n.a.	n.a.
Recruitment rate	0	++	++	0	0	NO	NO	n.a.	n.a.
Spatial distribution	+	+++	++	+	+	YES	YES	n.a.	YES
Dispersal	++	++	++	0	0	NO	NO	n.a.	n.a.
Emigration and immigration rate	++	++	++	0	0	YES	YES	n.a.	n.a.
Genetic diversity	++	+	+	0	0	NO	NO	n.a.	n.a.
Dolphin behavior metrics	0	+++	++	0	0	YES	NO	n.a.	n.a.
Prey abundance and distribution	+	++	+	0	0	NO	n.a.	n.a.	n.a.
		Bearzi et al. 2009	Fortuna et al. 2018, Bearzi et al. 2009, Bearzi et al. 2021	Alessi et al. 2019, Embling et al. 2015, Giovos et al. 2016	Manea et al. 2019, Farella et al. 2021				

The feasibility scoring for spatial distribution and abundance was based on the most commonly adopted monitoring approaches in the area, which are aerial and boat-based surveys (Fortuna et al., 2018; Bearzi et al. 2021), both time and resource consuming even if effective. However, more cost-effective techniques can be potentially adopted. For instance, Balmer et al. (2014) suggested a combined approach of vessel-based radio telemetry and automated radio telemetry systems (ARTS) as an effective and economically convenient approach to adopt to determine ranging patterns of tagged individuals. Spatial distribution and abundance data can be collected also with the involvement of citizens through citizen science initiatives (Embling et al., 2015; Giovos et al., 2016). Such initiatives are already present in certain critical areas for cetaceans in the Mediterranean (Alessi et al., 2019; Ricci et al., 2018).

Despite genetic diversity was scored lower than other variables, it is asked by policy frameworks and previous studies demonstrated the need to consider it, in combination with photo-identification and stable isotope analyses, for an effective study of fine-scale population structural and dispersal pattern of these species populations, as the one that inhabits the Croatian N2K sites (Gaspari et al., 2015).

Preys availability is a factor that affect to a lesser extent the distribution and health of bottlenose dolphins, which are not specialist and are able to shift preys on the base of the ones that are available (Holcer, 2012; Gaspari et al., 2015). However, prey depletion due to the excessive fishing pressure that affect the Northern Adriatic has been identified as one of the main issues to be addressed for dolphins conservation in the area (Bearzi et al., 2009). "Prey abundance and distribution" variable do not present high level of feasibility due to the cost and time needed for monitoring and because study on the prey selection by *T. truncatus* need to be improved. In addition, this cannot be monitored by citizens, neither used for ES assessment. Regardless of the limitations in monitoring this variable, it is important to keep the prey depletion issue under control and bypassing the monitoring limits through implementing precautionary and anticipatory measures limiting the fishing effort in the area.
Regarding the pressure variables (table 7), a good match was found with the criteria elements of the MSFD. Contaminants concentration and marine litter were the ones with the highest scores, because they are sensitive to changes and feasible to monitor, through agreed methodologies and protocols (EC report, 2013). However, while monitoring marine litter amount along the coast does not imply particular issues, extensive monitoring in the marine environment requires SCUBA dive and other supporting instruments, such as ROV, in order to cover large distance and to reach greatest depths (Rizzo et al., 2021). Such activity requires time and costs can increase depending on the extension of the monitoring area.
Despite the moderate level of feasibility, the main limitations for monitoring plastic and contaminants concentration in tissues and organs is that such analysis are based on stranded animals, meaning that such monitoring activities cannot be planned in advance, neither can be carried out systematically. Indeed, the lack of sensitivity to changes linked to this variable is due to these reasons, i.e., the impossibility to monitor it constantly and the absence of baseline information for comparison analysis. This is true also for "mortality rate from incidental by-catch or incidents with boats" and "interaction with fishing activities and fish farms". Nonetheless, these two variables could be monitored with the help of citizens, for instance fishermen and fish farmers, as well as boaters who go to sea during their leisure time. Noise pollution and its effect on common bottlenose dolphins emerged as one of the most sensitive variables, since it is directly linked to the level of vessel traffic. Monitoring studies that address underwater noise impact on *T. truncatus* are present in the area and already shared between Italy and Croatia in the framework of the Interreg IT-HR project "Soundscapes in the North Adriatic Sea and their

impact on Marine Biological Resources” (SOUNDSCAPE), which represents a first and virtuous coordinated approach to monitoring at the basin scale.

Overall, many of the ecological variables are already monitored in two out of the four N2K sites. Indeed, in Cres Losinj and Viski akvatori great effort is dedicated to the monitoring activities to assess constantly the state of this species thank to the work done by Blue World institute. On the contrary, in Tegnue di Chioggia and Trezze San Pietro and Bardelli we didn’t find information on monitoring of most of the variables. However, we acknowledge the great effort and contribution of the Dolphin Biology and Conservation association which carried out monitoring activities in the North Adriatic. The pressure variables are barely addressed through monitoring activities, and their integration is suggested.

Table 7. Score assigned to the pressure variables selected to monitor *T. truncatus* and information related to their actual monitoring.

Pressure variables to monitor *Tursiops truncatus*	Policy relevance	Sensitivity to change	Feasibility	Potential for citizens involvement	Data availability in Cres Losinj	Data availability in Viski akvatori	Data availability in Trezze San Pietro e Bardelli	Data availability in Tegnue di Chioggia
Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	++	**0**	**0**	**0**	NO	NO	n.a.	n.a.
interaction with fishing activities and fish farms (site fidelity, group dynamics, and seasonal and yearly occurrence)	**0**	**0**	++	+	YES	n.a.	n.a.	YES
contaminant concentration in water	++	+++	+++	**0**	n.a.	n.a.	n.a.	n.a.
contaminant concentration in tissues	++	++	++	**0**	NO	YES	n.a.	n.a.
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline	+	+++	++	+	n.a.	n.a.	n.a.	n.a.
the amount of litter and micro-litter	+	**0**	**0**	**0**	NO	NO	n.a.	n.a.

ingested, the number of individuals which are adversely affected due to litter								
spatial extent and duration of significant acute pollution events	+	+	+	0	n.a.	n.a.	n.a.	n.a.
effects of significant acute pollution events on the health of individuals and the condition of habitats	+	+	+	0	n.a.	NO	n.a.	n.a.
type, number and proximity of vessels to dolphins	0	+++	++	+	YES	NO	n.a.	YES
spatial distribution, temporal extent, and levels of noise pollution by traffic boats	+	+++	+	0	YES	NO	n.a.	n.a.
		Bearzi et al. 2009; Kershaw and Hall 2019; Schmid et al. 2021	Bearzi et al. 2009; Soundscape project; EC report 2013	Hidalgo-Ruz and Thiel 2015, Donnelly-Greenan et al. 2019, Currie et al. 2018				

5.2 Seagrass meadows

Seagrass meadows have high biological productivity and are rich, biodiverse habitats with numerous associated fish and invertebrate species. The most commonly present species in the ECOSS N2K sites is *Cymodocea nodosa.* The overall population of this species is thought to be stable, but a regression was noted in the northern Adriatic Sea mainly due to habitat degradation and mechanical damage from trawling and anchoring from boats and coastal development. Detailed information on this species is available in deliverable 4.2.1. Other species can be found, as *Nanozostera noltii* and *Zostera marina*. *Posidonia oceanica* was extensively present in the past, but at the end of the 60's it was strongly reduced, and especially in the North Adriatic this species is practically disappeared.

The scores assigned to the ecological variables selected to monitor seagrass meadows and the information related to their actual monitoring are reported in tables 8 and 9.

Regarding the ecological variables (table 8) proposed as of priority to monitor changes in seagrass meadows, the state of biomass, productivity, and density may indicate a variety of stresses, including dieback for physical and mechanical impacts, or chemical stresses for low water quality and pollution events (Fraser and Kendrick, 2017; Hossain and Hashim, 2019). Also in this case, spatial distribution, cover data and patch size are useful variables on which basing habitat suitability models (Cantucci and Scardi, 2020).

The variables mainly considered by the directives and monitoring frameworks we considered are biomass, cover and associated organisms. All other variables are scarcely represented by the policy instruments. However, several are the parameters that can give early information on variations of the health state of seagrass species. For instance, a three-months experiment of temperature variations to test for warming effects on *P. oceanica* and *C. nodosa* was enough to appreciate changes in growth rates, leaf formation and elongation rates and biomass (Olsen et al., 2012). We here generalized the adoption of monitoring indicators for seagrasses, even though we recognize that different seagrass species can give diverse answers to the same environmental variation and pressure source (Boudouresque et al., 2009; Jordà et al., 2012). Variation in recruitment rates can be detected within 18 months, which include the period that falls between seed germination and successful seedling establishment (Pereda-Briones et al., 2020). Spatial distribution and patches size can vary appreciably even yearly (especially patches size depending on their extent), but longer periods of time are usually considered for more reliable and consistent estimates (Danovaro et al., 2020). Epiphytes biomass is determined by several and unpredictable factors, depending on the epiphyte species, their interactions with the environment, the availability of their larvae and propagules, and the life-time of the seagrass leaf that they colonize (Borowitzka et al., 2007). For this reason, it is difficult to estimate the sensitivity of this monitoring variable. This consideration is true also considering all the species that live in association to the seagrass meadows, whether they are herbivores, invasive or other species. However, since they are strongly linked to the presence of this habitat and of the seagrass species that compose it, we expect the related monitoring variables being correlated with those described the seagrass state and fitness.

Regarding the feasibility, measures of coverage of seagrass meadows are fundamental, however their exhaustive collection is still not easy. Such measures depend on the depth at which seagrasses are distributed. Satellite and aerial imagery together with side scan sonar can be reliable approaches to collect coverage information even at large spatial scales (Greene et al., 2018; Paul et al., 2011). For small-scale measurements, SCUBA dive surveys, underwater videos and boat-based acoustic transect videography can be used (Schultz et al., 2011). In this case the instruments needed are less expensive, but the monitoring techniques are time-consuming and great effort is needed. Net primary production estimate requires diverse *in situ* measurements and is time consuming (Barron et al., 2006; Koopmans et al., 2020). Past studies highlighted the need to harmonized not only variables' terminology but also their definition, monitoring methods, and units of measures when dealing with seagrass monitoring activities (Lopez y Rojo et al., 2010). This is an additional effort that should be made to further harmonize monitoring activities to support the construction of coherent knowledge frameworks based on comparable and reliable data.

Table 8. Score assigned to the ecological variables selected to monitor seagrass species (i.e., *Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina*) and information related to their actual monitoring.

Ecological variables to monitor seagrasses (*Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina* associated to Habitat 1120*)	Policy relevance	Sensitivity to change	Feasibility	Potential for citizens involvement	Proxy for ecosystem services assessment	Data availability in Malonstonski zaljev	Data availability in Parco Delta del Po
Biomass	++	+++	+++	0	+	NO	NO
Cover	+++	+++	++	+	+	YES	NO
Growth rate	+	+++	+++	0	+	NO	NO
Recruitment rate	0	+++	++	0	+	NO	NO
Leaf elongation rate	0	+++	+++	0	+	NO	NO
Net primary production	+	+++	++	0	+	NO	NO
Erosion-recolonization rate	0	+	++	0	+	NO	NO
Spatial distribution	+	++	++	+	+	YES	NO
Patch size	+	++	+++	+	+	NO	NO
Biometric measures	0	+++	+++	+	+	NO	NO
Phenological measures	+	+++	+++	+	+	NO	NO
Genetic diversity	+	+	++	0	0	NO	NO
Associated organisms	+++	n.a.	+++	+	0	YES	NO
Habitat characterization	0	n.a.	+++	+	0	YES	NO
presence/abundance/percentage cover of invasive species	+	n.a.	+++	+	0	YES	NO
density and abundance of herbivores	+	n.a.	+++	+	0	NO	NO
biomass of epiphytes	+	n.a.	+++	0	0	NO	NO
		Olsen et al. 2012; Pereda-Briones et al. 2020; Danovaro et al. 2020	Lopez y Royo et al. 2010; Abadie et al. 2019; Hossain & Hashim 2019; Barrón et al. 2006;	Jones et al. 2018; Smale et al. 2019; Mannino and Balistreri 2018	Hossain & Hashim 2019; Ruiz-Frau et al. 2017; Nordlund et al., 2018; de		

			Koopmans et al. 2020; Pereda-Briones et al. 2020		los Santos et al. 2020		

In this regard, it is interesting that most of the ecological variables proposed to monitor seagrasses are already commonly adopted in national monitoring activities, as most of them possess dedicated methodologies (Lopez y Rojo et al., 2010). Nonetheless, scarce is their level of relevance from a policy perspective since few of them fall in the list of the monitoring frameworks of WFD and MSFD. This confirms again that there is a lack of guidance from these policy instruments on how to monitor seagrass meadows, and, likely for this reason, the monitored variables and methods adopted were developed independently of them. This clearly contributes to the lack of harmonization of monitoring approaches at regional level, as it might be the case of the Adriatic basin.

Seagrass meadows provide many ES: they are nursery, feeding and protection habitats for many marine species; they contribute to water quality improvement through sediment stabilization, nutrient cycling, wave attenuation, harmful marine pathogen reduction; they stabilize coastal areas by contrasting coastal erosion processes; they are recognized as organisms able to contribute to blue carbon sequestration and storage; they support recreational activities and cultural services (Ruiz-Frau et al., 2017; de los Santos et al., 2020). Seagrass distribution and cover estimates are commonly adopted as proxy of ES provisioning. High-resolution and hyperspectral satellite sensors can be useful instruments to provide such data, as well as the use of drone or acoustic technologies, like hydro-acoustic sensors such as ecosounders (Hossain et al., 2015; Hossain and Hashim, 2019). These approaches might also be useful to detect structural characteristics of seagrass canopy coverage, which might be adopted as proxies for assessing their capability of carbon storage (Falco et al., 2010). Leaf elongation rate and biometric measures, as well as biomass, are all variables suitable for estimating carbon sequestration potential of seagrasses. Growth and recruitment rates, as well as primary productivity, can be adopted for seagrass productivity mapping. We found citizen-science approaches being of relevant importance in contributing to monitor diverse ecological variables related to seagrasses (Jones et al., 2018; Smale et al., 2019; Mannino and Balistreri, 2018). For instance the National Marine Aquarium in Plymouth UK, carried out the Community Seagrass Initiative (CSI), a citizen science project during which citizens were involved in data collection to assess

the distribution and state of *Zostera marina* (Smale et al., 2019). Also in relation to monitoring invasive species, an important contribution has been done in Egadi Islands MPA (Mannino and Balistreri, 2018).
Regarding the pressure variables (table 9), contaminant concentration in environmental matrices and organisms tissues present higher scores, as well as pollution events. This is partly because both the MSFD and WFD consider these variables, which monitoring has been prescribed for a long time, especially for organisms used as models in toxicological studies. This is also why the level of feasibility is high.
Changes in hydrographic conditions are already monitored in the ECOSS area, thanks to the presence of the fixed monitoring systems described in deliverable 3.1.1. However, the sensitivity to changes of this variable is difficult to estimate since it depends on the local scale considered.
Presence/abundance/percentage cover of invasive species presented a medium score. Invasive species have been recognized as the second most common cause of loss of biodiversity, being a potential driver of impact to trophic food webs and ecosystem functioning (Bellard et al., 2016; Giakoumi et al., 2019; Armeli Minicante et al., 2020). Their monitoring is important, despite the absence of baseline information, also considering the possible contribution citizens can give. Decision-support tools are being testing and are available to support invasive species monitoring also engaging the civil society and stakeholders (Copp et al., 2021).
Overall, the data related to the ecological and pressure variables here considered for monitoring seagrass meadows are barely collected in the two N2K sites that host them. If in Malostonsky zaljev some of them are considered and monitored, in Parco Delta del Po the monitoring of seagrasses is completely absent.

Table 9. Score assigned to the pressure variables selected to monitor seagrass species (i.e., *Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina*) and information related to their actual monitoring.

Pressure variables to monitor seagrasses (*Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina* associated to Habitat 1120*)	Policy relevance	Sensitivity to change	Feasibility	Potential for citizens involvement	Data availability in Malonstonski zaljev	Data availability in Parco Delta del Po
Presence/abundance/percentage cover of invasive species	+	++	++	+	YES	NO
contaminant concentration in water and sediment	++	+++	+++	**0**	NO	NO
area cover destructed by anchoring-trawling	+	+++	++	**0**	YES	NO
intensity and spatial and temporal variation of physical disturbance	+	++	++	**0**	YES	NO
spatial extent of each habitat type which is adversely affected, through change in	+	++	++	**0**	YES	NO

its biotic and abiotic structure and its functions by physical disturbance						
spatial and temporal variation of hydrographical conditions	+	n.a.	++	0	NO	NO
spatial extent of each habitat type adversely affected due to alteration of hydrographical conditions	+	++	++	0	NO	NO
spatial extent and duration of significant acute pollution events	+	+++	+++	0	NO	NO
effects of significant acute pollution events on the health of individuals and the condition of habitats	+	+++	+++	0	NO	NO
heavy metal and organic pollutant concentration in tissues	++	+++	+++	0	NO	NO
amount and weight of litter and micro-litter in the water column and on the seafloor	+	+++	++	+	NO	NO
		Boutahar et al. 2021; Richir et al. 2013; Danovaro et al. 2020; Li & Tanhua 2020; Stipek et al. 2020; Schmid et al. 2021	Boutahar et al. 2021; Matić et al. 2017; Vilibić et al. 2019; Copp et al. 2021; Stipek et al. 2020; Kreitsberg et al. 2021	Mannino and Balistreri 2018; Hidalgo-Ruz and Thiel 2015		

5.3 *Pinna nobilis*

Pinna nobilis is endemic to the Mediterranean Sea, where it lives offshore at depths ranging between 0.5 and 60 m, and is the largest Mediterranean bivalve species that can reach up to 120 cm of shell length. It is relatively sensitive to pollution and shell damage. Since about three years, *P. nobilis* has been undergoing a mass die-off that is bringing this species to the brink of extinction throughout the Mediterranean. For this reason, numerous studies are now aimed at understanding the reason for this death, to guide conservation and restoration actions of this species. Thus monitoring *P. nobilis* is of great priority and urgency today. Detailed information on this species can be found in deliverable 4.2.1.
The scores assigned to the ecological variables selected to monitor seagrass meadows and the information related to their actual monitoring are reported in tables 10 and 11.
P. nobilis presents a certain degree of plasticity, being able to live in both marine and transitional environments, such as lagoons. Thus, each ecological variable related to the individuals of this species, as growth and recruitment rates and biometric measures, might respond differently depending on the

environmental conditions to which the population is subjected (Richardson et al., 2004; García-March et al., 2020). In addition, diverse are the oceanographic variables that may affect pen shells orientation, e.g., wave height and direction, bottom current direction and speed (Coppa et al., 2013). Therefore, most ecological variables possess a high level of sensitivity to changes, suitable to be adopted as early warning. Modelling approaches can be also used to estimate growth and mortality rates of *P. nobilis* (e.g., Katsanevakis et al., 2007). The adoption of such approaches is useful and cost-effective; however to feed them it is necessary to collect relevant and reliable *in situ* data for long-time period.

P. nobilis is able to provide diverse ES: it filters water by retaining large amounts of organic matter from suspended detritus and contributing to water clarity; its shell provides a hard-surface for different benthic species that colonize it by creating high-diversity biogenic reefs; it also plays a key role in the trophic web, serving as prey of other species and host of symbiont (Cabanellas-Reboredo, et al. 2019 and references therein). Density, population size and spatial distribution can serve as proxy for ES provisioning assessment and mapping. Half of the ecological variables are considered in the monitoring policy frameworks, with the exception of the EOV that does not consider in its functional groups benthic invertebrates other than corals. In this case, the EOV approach is not of support and cannot be applied to monitor this highly threatened species.

Regarding citizens involvement, diverse initiatives are on track to both gather spatial information on this species distribution as well as to monitor the extent of the existing pandemic, also in the North Adriatic (Cabanellas-Reboredo, et al. 2019, Smale et al., 2020; Mannino and Balistreri, 2018; “Mappa la pinna” intiative, https://cutt.ly/pinna).

Table 10. Score assigned to the ecological variables selected to monitor *Pinna nobilis* and information related to their actual monitoring.

Ecological variables to monitor *Pinna nobilis*	Policy relevance	Sensitivity to change	Feasibility	Potential for citizens involvement	Proxy for ecosystem services assessment	Data availability in Malonstonski zaljev	Data availability in Trezze San Pietro e Bardelli	Data availability in Parco Delta del Po
biometric measures	+	+++	+++	0	0	YES	YES	n.a.
density	0	+++	++	0	+	YES	YES	n.a.
age	++	0	+++	0	0	NO	NO	n.a.
population size	0	+++	++	0	+	YES	NO	n.a.
birth-growth-mortality rates	++	+++	++	0	0	YES	YES	n.a.

spatial distribution	+	+++	++	+	+	YES	YES	n.a.
genetic diversity	+	+	++	0	0	NO	NO	n.a.
spawning rate	+	+++	++	0	0	YES	NO	n.a.
settlement and recruitment rate/success	+	+++	++	0	0	YES	NO	n.a.
shell burial level and orientation	0	+++	+++	0	0	NO	NO	n.a.
habitat characterization	0	n.a.	+++	+	0	YES	YES	n.a.
associated organisms	+++	n.a.	+++	+	0	YES	NO	n.a.
mortality rate due to pandemic events	0	+++	+++	+	0	YES	YES	n.a.
interaction with other species	+	n.a.	+++	0	0	NO	NO	n.a.
presence/abundance/ cover of invasive species	+	n.a.	+++	+	0	YES	NO	n.a.
		Richardson et al. 2004; García-March et al. 2020a; García-March et al. 2020b; Coppa et al. 2013	Richardson et al. 2004; García-March et al. 2020a; Coppa et al. 2013; López-Sanmartín et al. 2019	Cabanellas-Reboredo et al. 2019; Smale et al. 2020; Mannino and Balistreri 2018	Cabanellas-Reboredo et al. 2019			

The health of *P. nobilis* populations was found to be highly affected by human pressures, even more than environmental conditions (Deudero et al., 2015), thus highlighting the need to monitor human-induced impacts and to relate ecological variables (such as density and population sizes) to those of pressure. Regarding pressure variables (table 11), scoring criteria followed the same approach applied for seagrasses (i.e., contaminant concentration, marine litter amount and distribution, acute pollution events, variations in hydrographical conditions, presence/abundance/percentage cover of invasive species).

Overall, different ecological variables are already monitored in Malostonski zaljev and Trezze San Pietro and Bardelli, with effort and constancy. On the contrary, the pressure variables are mainly neglected. Considering the pandemic that is affecting this species, the integration of pressure variables within the monitoring activities carried out is suggested since other pressures could have synergistic effects on *P. nobilis* together with those linked to this mortality event. To our knowledge, no monitoring activities are carried out in Tegnue di Chioggia.

Table 11. Score assigned to the pressure variables selected to monitor *Pinna nobilis* and information related to their actual monitoring.

Pressure variables to monitor *Pinna nobilis*	Policy relevance	Sensitivity to change	Feasibility	Potential for citizens involvement	Data availability in Malonstonski zaljev	Data availability in Trezze San Pietro e Bardelli	Data availability in Parco Delta del Po
presence/abundance/ cover of invasive species	+	++	++	+	YES	NO	n.a.
heavy metal and organic pollutant concentration in water	++	+++	+++	**0**	NO	YES	n.a.
heavy metal and organic pollutant concentration in tissues	++	+++	+++	**0**	NO	n.a.	n.a.
signs of injury	+	+++	+++	+	YES	n.a.	n.a.
mortality rate due to anchoring-fishing-diving	+	+++	++	**0**	NO	n.a.	n.a.
spatial and temporal variation of hydrographical conditions	+	**n.a.**	++	**0**	NO	YES	YES
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	+	++	++	**0**	NO	NO	n.a.
spatial extent and duration of significant acute pollution events	+	+++	+++	**0**	NO	NO	n.a.
effects of significant acute pollution events on the health of individuals and the condition of habitats	+	+++	+++	**0**	NO	NO	n.a.
intensity and spatial and temporal variation of physical disturbance	+	++	++	**0**	YES	NO	n.a.
spatial extent of the suitable habitat which is adversely affected through change in its biotic and abiotic structure and its functions by physical disturbance	+	++	++	**0**	NO	NO	n.a.
amount and weight of litter and micro-litter in the water column and on the seafloor	+	+++	++	+	NO	NO	n.a.
		Vazquez-Luis et al. 2015; Deudero et al. 2015; Schmid et al. 2021	Matić et al. 2017; Vilibić et al. 2019; Rizzo et al. 2021	Mannino and Balistreri 2018; Hidalgo-Ruz and Thiel 2015			

With regard to allelic diversity, we found low scores in relation for *P. nobilis*, as for the other target species here considered. Allelic diversity is defined as the average number of alleles per locus in a population of a given species (Allendorf, 1986; Schmeller et al., 2018). As such, allelic diversity is a measure of genetic diversity that can be related to a population's long-term potential for adaptability and persistence in the face of future changes (Schmeller et al., 2018). Thus, its assessment and monitoring over time is critical, even though this variable is not operationally quick, since it takes time to express detectable changes. Nonetheless, we found only the EBV framework considering such monitoring variables despite its relevance. This gap within the policy framework might be due to the diverse limitations, mainly related to the fact that population genetics is a relatively young research field. Methods to carry out related research have expanded without a coordinated approach, costs are still high, and there is no common database reporting allelic diversity information related to many species (Schmeller et al., 2018). Sampling is often restricted to populations and areas at small spatial and temporal scales and for a restricted number of loci. An important concerted effort would be needed to implement such studies at the basin scale. However, starting at the smaller scale of N2K sites could be a manageable and important starting point.

6. LESSONS LEARNT AND FUTURE PERSPECTIVES OF ECOAdS IN RELATION TO DIRECTIVES

In this deliverable, we delineated the essential attributes that ECOAdS includes as a decision-support tool for the responsible authorities and agencies of N2K sites, to favour the overcoming of the main issues that hinder N2K implementation and efficacy. These are: (i) an agreed conceptual framework for the harmonization of monitoring schemes, data acquisition and analysis at trans-regional and national levels; (ii) data platforms to deliver oceanographic and ecological information and knowledge, fully adopting the open science approach; (iii) tight cooperation among the fragmented multi-level GMS and responsible managing authorities of N2K sites; (iv) local ecological knowledge and priorities integration for the effective involvement of stakeholders and the civil society within the mechanism of knowledge co-production (Manea et al., 2020). These attributes have been identified on the base of the needs and gaps that we recognized in the Adriatic basin and at the level of the N2K network – i.e., absence of management plans at the level of N2K sites; absence of coordination of governance, management and monitoring systems at the basin scale; need to enlarge the N2K network at the Adriatic level considering also offshore ecosystems and including ecological connectivity aspects.

The characterization of ECOAdS was followed by the analysis of the synergies and the complementarities among the main EU directives addressing marine conservation. Such synergies are crucial since the monitoring under the Nature directives is weakly implemented mainly because of the absence of management plans, as well as for shortcomings of dedicated funds. We here suggested the WFD and MSFD monitoring programs as important instruments to monitor N2K sites and to assess their environmental state, and we envisaged joint monitoring programs and their integration as a winning strategy to avoid the neglect of some marine areas, especially at the interfaces (e.g., land-sea, coastal-offshore waters). This would be relevant to address ecological connectivity information in monitoring strategies, even beyond conservation sites, to fit the transboundary context that is the Adriatic Sea.
ECOAdS is thus proposed as an instrument able to boost such coordination and synergies, to favour the integration of these monitoring efforts at multiple scales and to inform management and conservation practices and the spatial planning at the Adriatic Sea scale.
Starting from the ECOSS conceptual model and the comparative analysis among the four directives, as a first contribution we made an attempt to harmonize their monitoring approaches, starting from the terminology adopted to guide them towards the achievement of their conservation and management objectives. Matches and mismatches were drawn, with the aim to align the descriptive monitoring indicators listed in the directives monitoring frameworks. We considered also the EBVs and EOVs in a way to test the level of applicability of these two frameworks at the small scale of the N2K sites, as well as the potentiality of ECOAdS to feed them and to support their implementation at larger scale. We finally reviewed the monitoring indicators already collected in the area on the base of the existing monitoring initiatives and projects. This information is relevant to assess what is already monitored in the N2K sites of ECOSS, despite the absence of systematic monitoring activities, to identify the presence of possible long-time series of data on which to build a structured monitoring, as well as the monitoring gaps that need to be filled.

We found that at least one of the diverse monitoring frameworks we considered (WFD and MSFD directives and EOVs and EBVs frameworks) cover most of the monitoring variables identified as of priority for the monitoring of target species and habitats present in the N2K sites case study. Especially, the EBVs cover most of the ecological variables selected, as they were built to satisfy most of the criteria we adopted for variables' selection (Schmeller et al., 2018) and are representatives of biodiversity state.

These variables should be considered in the future establishment of management and related monitoring programs for N2K sites. Nonetheless, if EBVs and EOVs had not been considered, the directives would not have represented several priority variables, for instance, genetic diversity and reproduction related ones (e.g., spawning and recruitment rate). This can be partly explained by the limited feasibility of monitoring and collecting them. However, they are also the ones relevant to address the ecological connectivity aspects. Indeed, migration patterns, recruitment rate, spatial distribution and dispersal, genetic diversity are all highly representative of connectivity aspects, and interactions between species and preys are variables that support ecosystem functioning studies. These variables are important to both assess and monitor the state of target species and habitats at both the N2K sites and basin level, as well as to guide N2K sites expansion and identification of novel sites to designated, considering also offshore areas. Thus, we call for an operative integration of such variables at the scale of the N2K sites.

When we focused on pressure variables, we found the MSFD be the only instruments that address them. Pressure variables have been identified as fundamental when monitoring programs aim at informing management (Dunham et al., 2020). Monitoring pressures, especially when the levels of pressure bearing of a species or habitat are known, can really allow anticipating an impact. Indeed, ecological variables best inform pressure effects on species and habitats, but only waiting for ecological signals might be ineffective when conservation is the aim. Pressures and human uses from which they derive must be monitored, anticipated and managed to avoid environmental degradation, informing an adaptive and anticipatory management.
As such, an effective early warning framework should include pressure variables and adopt composite indicators, able to depict the health state and trajectory of a species, population, habitat, and to allow to test for correlation among variables that determine this state (Schmeller et al., 2018).

We proposed here an approach to develop a coherent ecosystem-based indicators system for monitoring target species and habitats of N2K sites. This approach allowed us to bring out possible limitations to monitoring, as well as opportunities (e.g., new technologies to support monitoring, the monitoring of proxies for ES assessment, and the application of citizen science approach to boost monitoring effectiveness), and to guide possible prioritization of monitoring variables to support conservation of target specie and habitats in N2K sites. Linked to one of the criteria on which ECOAdS is built, we support citizen science approach to monitoring, as we believe it can be a way to engage citizens, sharing visions and research questions with them in a reciprocal knowledge exchange, and involving them in the observations, as a further support for large-scale and cost-effective monitoring initiatives (Couvet et al. 2008; Jones et al., 2018). Although a main concern of citizen science studies is the level of reliability of the collected information, which requires clear protocols, training of volunteers and a quality check by professional scientists, this approach has been confirmed as useful (Hidalgo-Ruz and Thiel, 2015; Matear et al., 2019; Turicchia et al., 2021).

ECOAdS represents a pilot project at the scale of the Adriatic, but there is the need to upscale coordinated monitoring efforts and early-warning systems to provide datasets with extensive temporal and spatial coverage, relevant and reliable to support and inform biodiversity and ecosystems protection. What is foreseeable in the future to improve our understanding of the condition of the marine ecosystems are: standardized monitoring methodologies with harmonized terminologies; setting up of management and systematic monitoring plans at the level of N2K sites; increased sampling effort in time and space monitoring to build baseline information and considering connectivity elements; improved access to historical and new data at transnational level; sustained engagement of national stakeholders also to provide them relevant information to foster sustainability practices (Bax et al., 2018). Overall, ECOAdS represents the opportunity to build a common knowledge and monitoring framework at a transnational level to overcome the N2K sites fragmentation, incorporating marine connectivity aspects and supporting coordination in planning and managing the Adriatic Sea.

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8. ANNEX

Annex I

The analogy we propose here to link the ecological and oceanographic variables to be adopted in N2K sites, the EU directives' descriptive indicators, and the EOV and EBV does not reflect the complexity of drawing comparisons between different properties of the marine environment in terms of ecological and oceanographic processes and biodiversity, and of all these monitored and assessed at different scales. It is a first attempt to compare different monitoring frameworks to explore the possibility of integrating them with each other and making them complementary, aware of the different approaches and spatial scales on which they act by their nature.

Table A1. List of ecological variables identified as of priority to monitor *Tursiops truncatus* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Tursiops truncatus*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
Density			density (DP)	
Abundance	Representative species abundance (D1C2, D1C4, D1C5)		count data (SbV)	population abundance
Sex	Representative species sex structure (D1C3)		sex (SbV)	population structure by age/size class
Age	Representative species age structure (D1C3)		age (SbV)	population structure by age/size class
Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	Representative species fecundity rate (D1C3)			demographic traits
	Representative species survival rate (D1C3)			
	Mortality rate of anthropogenetic activities (D1C1)			
	Injury rate of anthropogenetic activities (D1C1)			
	Representative species mortality rate (D1C2, D1C3)			
	Representative species injury rate (D1C2, D1C3)			
Recruitment rate				
Spatial distribution			distribution (EOV)	species distribution
Dispersal	Representative species distribution (D1C4)		home range (DP) e utilization distribution (DP)	migratory behavior

Emigration and immigration rate	Migration (D1C3)		migration patterns (DP)/movement patterns (DP)	migratory behaviour
Genetic diversity				allelic diversity
Dolphin behavior metrics				
Prey abundance and distribution			Prey availability/diet (CV)	

Table A2. List of pressure variables identified as of priority to monitor *Tursiops truncatus* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor *Tursiops truncatus*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	Representative species fecundity rate (D1C3)			
	Representative species survival rate (D1C3)			
	Mortality rate of anthropogenetic activities (D1C1)			
	Injury rate of anthropogenetic activities (D1C1)			
	Representative species mortality rate (D1C2, D1C3)			
	Representative species injury rate (D1C2, D1C3)			demographic traits
interaction with fishing activities and fish farms (site fidelity, group dynamics, and seasonal and yearly occurrence)				
contaminant concentration in water		Pollution by all priority substances identified as being discharged into the body of water		
	concentration of contaminants (D8C1)	Pollution by other substances identified as being discharged in significant quantities into the body of water		
contaminant concentration in tissues		Bioaccumulation		
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			

	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter	amount of litter ingested by marine animals (D10C3)			
	amount of micro-litter ingested by marine animals (D10C3)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
type, number and proximity of vessels to dolphins				
spatial distribution, temporal extent, and levels of noise pollution by traffic boats	Temporal extent of anthropogenic impulsive sound sources (D11C1)			
	Levels of anthropogenic impulsive sound sources (D11C1,D11C2)			

Table A3. List of oceanographic variables identified as of priority to monitor *Tursiops truncatus* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Tursiops truncatus*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
temperature	Temperature (D1C6, D5C4, D7C1)	temperature	temperature (CV)	
dissolved oxygen	Dissolved oxygen (D5C5)	dissolved oxygen	dissolved oxygen (CV)	
Salinity	salinity (D1C6)		surface and subsurface salinity (EOV Oxygen)	
Chl-a	Chl-a (D5C2)		Ocean colour (chlorophyll-a concentration) (EOV Particulate matter	
Transparency	Transparency (D5C4)	Secchi depth		
pH	pH/pCO2 (D1C3, D5C5)	pH		
		Total nitrogen	Nutrients (SV)	

nutrient concentration in water and sediments	Nutrient concentrations (D5C1)	Total phosphorus		
		Soluble reactive phosphorus		

Table A4. List of ecological variables identified as of priority to monitor *Fucus virsoides* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Fucus virsoides*	MSFD	WFD	EOV Macroalgal canopy cover and composition; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
biomass			Photosynthetic biomass (SbV)	population abundance
cover	Macrophyte depth distribution (D5C7)	Vegetation cover/Distribution cover of macroalgae	Areal extent (SbV)	population abundance
density				
abundance	Macrophyte abundance (D5C7)	Abundance of aquatic flora (macrophyte)		population abundance
growth-mortality rates	Representative species fecundity rate (D1C3)			demographic traits
	Representative species survival rate (D1C3)			
	Representative species mortality rate (D1C3)			
	Representative species injury rate (D1C3)			
photosynthetic activity			Photosynthetic efficiency (SbV)	
net primary productivity			Primary production (DP)	net primary productivity (NPP)
spatial distribution				species distribution
spawning rate				demographic traits
spawning stock biomass				
biometric measures			Canopy height (SbV)	
phenological measures				phenology
genetic diversity				allelic diversity
settlement and recruitment rate				demographic traits
associated organisms	Benthic species composition (D6C5)	Composition of fish fauna	Species composition and abundance of associated fish assemblages (CV)	taxonomic diversity
		Composition of invertebrate fauna	Species composition and abundance of understory assemblages (CV)	
	Benthic species abundance (D6C5)	Abundance of invertebrate fauna		

presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
density and abundance of herbivores	Benthic species abundance and composition (D6C5)			
area covered by suitable habitats and their structure				
cover of opportunistic species				

Table A5. List of pressure variables identified as of priority to monitor *Fucus virsoides* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor *Fucus virsoides*	MSFD	WFD	EOV Macroalgal canopy cover and composition; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
heavy metal and organic pollutant concentration in tissues		Bioaccumulation		
effect of trampling				
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
contaminant concentration in water	concentration of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
spatial extent of the suitable habitat which is adversely affected through change in its biotic and abiotic	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its			

structure and its functions by physical disturbance spatial and temporal variation of hydrographical conditions	functions by physical disturbance (D6C3)			
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	Spatial extent of permanent alteration of hydrographical conditions to the seabed and water column (D7C2)			
	Distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C2)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			

Table A6. List of oceanographic variables identified as of priority to monitor *Fucus virsoides* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Fucus virsoides*	MSFD	WFD	EOV Macroalgal canopy cover and composition; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
air and water temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	Temperature (SV)	
salinity	salinity (D1C6)		Salinity (SV)	
PAR			PAR (SV)	
Chl-a	Chl-a (D5C2)		Ocean colour (chlorophyll-a concentration) (EOV Particulate matter)	
Dissolve oxygen	Dissolved oxygen (D5C5)	dissolved oxygen	dissolved oxygen (EOV Oxygen)	
Transparency	Transparency (D5C4)	Secchi depth	water clarity (SV)	
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	
type of substratum	substrate type (D6C5)		Substratum type (SV)	
wind exposure				
wave exposure				
slope				
current velocity	current regime (D1C6)			
current direction	current regime (D1C6)			
nutrient concentration in water and sediments	Nutrient concentrations (D5C1)	Total nitrogen	Nutrients (SV)	
		Total phosphorus		

		Soluble reactive phosphorus		
relative exposure index (REI)				

Table A7. List of ecological variables identified as of priority to monitor seagrasses and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor seagrasses (*C. nodosa, P. oceanica, N. noltii, Z. marina* associated to Habitat 1120*)	MSFD	WFD	EOV Seagrass cover and composition; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
biomass	Benthic species biomass (D6C5)		Seagrass biomass (CV)	population abundance
cover	Benthic species coverage of seabed (D6C5)	Depth/Distribution cover of angiosperms	Shoot density/cover (SbV)	
	Macrophyte depth distribution (D5C7)			
growth rate				demographic traits
recruitment rate				
leaf elongation rate				
net primary productivity			Primary and secondary production (DP)	net primary productivity (NPP)
erosion-recolonization rate				
spatial distribution			Global and regional seagrass distribution (DP)	species distribution
patch size			Areal extent of seagrass meadows (SbV)	habitat structure
biometric measures				
phenological measures				phenology
genetic diversity				allelic diversity
associated organisms	Benthic species composition (D6C5)	Composition of fish fauna	Algal abundance/biomass (CV)	taxonomic diversity
		Composition of invertebrate fauna	Epifaunal abundance (CV)	
	Benthic species abundance (D6C5)	Abundance of invertebrate fauna	Fish abundance and species composition (CV)	
			Invertebrate abundance and species composition (CV)	
habitat characterization	Benthic habitat distribution (D6C5)			
	Benthic habitat extent (D6C5)			
	Benthic habitat volume (D6C5)			
presence/abundance/percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
density and abundance of herbivores	Benthic species abundance (D6C5)			

biomass of epiphytes			Epiphytic algae and fouling load (SV)	

Table A8. List of pressure variables identified as of priority to monitor seagrasses and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor seagrasses (*C. nodosa, P. oceanica, N. noltii, Z. marina* associated to Habitat 1120*)	MSFD	WFD	EOV Seagrass cover and composition; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
contaminant concentration in water	concentration of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
area cover destructed by anchoring-trawling	Benthic habitat distribution (D6C5)			
	Benthic habitat extent (D6C5)			
	Benthic habitat volume (D6C5)			
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance (D6C3)			
spatial and temporal variation of hydrographical conditions	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C1)			
spatial extent of each habitat type adversely affected due to alteration of hydrographical conditions	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions (D7C2)			
	Spatial extent of significant acute pollution events (D8C3)			

spatial extent and duration of significant acute pollution events	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
heavy metal and organic pollutant concentration in tissues		Bioaccumulation		
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			

Table A9. List of oceanographic variables identified as of priority to monitor seagrasses and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor seagrasses (*C. nodosa, P. oceanica, N. noltii, Z. marina* associated to Habitat 1120*)	MSFD	WFD	EOV Seagrass cover and composition; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
air and water temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	Temperature (SV)	
salinity	salinity (D1C6)		Salinity (SV)	
PAR				
Chl-a	Chl-a (D5C2)		Ocean colour (chlorophyll-a concentration) (EOV Particulate matter)	
Dissolve oxygen	Dissolved oxygen (D5C5)	dissolved oxygen	dissolved oxygen (EOV Oxygen)	
Transparency	Transparency (D5C4)	Secchi depth	water clarity (SV)	
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	
Wave exposure				
depth				
current velocity	current regime (D1C6)			
current direction	current regime (D1C6)			
Sediment type	substrate type (D6C5)	Particle size of the bed		
Sedimentation rate				
Nutrient concentration in water and sediments	Nutrient concentrations (D5C1)	Total nitrogen	Inorganic macronutrients (nitrate, ammonium, phosphate) (CV)	
		Total phosphorus		
		Soluble reactive phosphorus		
Redox potential				

Oxygen concentration in sediments	Oxygen level (D6C5)			
organic matter in sediments	organic carbon (D6C5)	Organic content of the bed		

Table A10. List of ecological variables identified as of priority to monitor *Pinna nobilis* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Pinna nobilis*	MSFD	WFD	EOV	EBV
biometric measures	Representative species size structure (D1C3)			population abundance
density				
age	Representative species age structure (D1C3)			population structure by age/size class
Population size				
Birth-growth-mortality rates	Representative species fecundity rate (D1C3)			demographic traits
	Representative species survival rate (D1C3)			
	Representative species mortality rate (D1C3)			
spatial distribution				species distribution
genetic diversity				allelic diversity
spawning rate				demographic traits
settlement and recruitment rate				demographic traits
Shell burial level and orientation				
Habitat characterization				
associated organisms	Benthic species composition (D6C5)	Composition of fish fauna		taxonomic diversity
		Composition of invertebrate fauna		
	Benthic species abundance (D6C5)	Abundance of invertebrate fauna		
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
Mortality due to *Haplosporidium pinnae*				
Interaction with other species				Species interactions

Table A11. List of pressure variables identified as of priority to monitor *Pinna nobilis* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to *Pinna nobilis*	MSFD	WFD	EOV	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
heavy metal and organic pollutant concentration in tissues		Bioaccumulation		
contaminant concentration in water	concentration of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
Signs of injury	Representative species injury rate (D1C2,C3)			
mortality rate due to anchoring-fishing-diving	Representative species injury rate (D1C2,C3)			
spatial and temporal variation of hydrographical conditions	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C1)			
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions (D7C2)			
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance (D6C3)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			

Table A12. List of oceanographic variables identified as of priority to monitor *Pinna nobilis* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Pinna nobilis*	MSFD	WFD	EOV	EBV
air and water temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	EOV Subsurface temperature	
salinity	salinity (D1C6)		Surface and subsurface Salinity (EOV nutrients)	
Chl-a			chl a (EOV ocean colour)	
Dissolve oxygen	Dissolved oxygen (D5C5, D6C3, D6C5, D7C2)	dissolved oxygen	EOV oxygen	
Transparency	Transparency (D5C4)	Secchi depth		
pH	pH (D1C6, D5C1, D5C5)	pH	pH (EOV Inorganic carbon)	
Wave exposure				
current velocity	current regime (D1C6)			
current direction	current regime (D1C6)			
Sediment type	substrate type (D6C5)	Particle size of the bed		
Sedimentation rate				
Nutrient concentration in water and sediments	Nutrient concentrations (D5C1)	Total nitrogen	EOV nutrients	
		Total phosphorus		
		Soluble reactive phosphorus		
Redox potential				
organic matter in sediments	organic carbon (D6C5)	Organic content of the bed		

Table A13. List of ecological variables identified as of priority to monitor *Alosa fallax* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Alosa fallax*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
density			Number, biomass or abundance index of fish of different taxa per unit volume or area of water in a specific region, stock or population, and measured by a standard or known protocol (SbV)	
abundance	commercially-exploited species abundance (D3C3)	Abundance of fish fauna	fish abundance (EOV)/fish abundance indeces (DP)	population abundance
	Representative species abundance (D1C2,C4,C5)			
biomass	commercially-exploited species biomass (D3C3)		number or biomass of fish by size/age/stage (SbV)	population abundance
biometric measures	commercially-exploited species size structure (D3C3)			

Birth-growth-mortality rates	commercially-exploited population fecundity (D3C3)	Life cycle of fish fauna		demographic traits
	commercially-exploited population survival (D3C3)			
	commercially-exploited population mortality/injury rates (D3C3)			
age	commercially-exploited species age structure (D3C3)	Age structure of fish fauna	Numbers or biomass of fish by size/age/stage (SbV)	population structure by age/size class
spawning rate and stock biomass	commercially-exploited species biomass (D3C2)			demographic traits
recruitment rate				demographic traits
timing and duration of the estuarine phase				physiological traits
spatial distribution			fish distribution EOV	species distribution
spatial movements/migration rate	Species distribution (location) (D3C2)			migratory behavior
	behavior including movement and migration (D3C3)			
presence/abundance/ cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
genetic diversity			fish diversity indices (DP)	allelic diversity
competition with other species				Species interactions
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms	Number of harmful algal bloom events (D5C3)			
	Duration of harmful algal blooms events (D5C3)			
	Spatial extent of harmful algal blooms events (D5C3)			

Table A14. List of pressure variables identified as of priority to monitor *Alosa fallax* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor *Alosa fallax*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
contaminant concentration in tissues	level of contaminants in edible tissues (D9C1)	Bioaccumulation		
fishing mortality rate	commercially-exploited species mortality rate (D3C1)			

number and type of barriers to migration				
spatial and temporal variation of hydrographical conditions	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C1)			
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions (D7C2)			
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance (D6C3)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter	amount of litter ingested by marine animals (D10C3)			
	amount of micro-litter ingested by marine animals (D10C3)			

Table A15. List of oceanographic variables identified as of priority to monitor *Alosa fallax* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Alosa fallax*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV

water temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	temperature (CV)	
salinity	salinity (D1C6)		salinity (CV)	
Chl-a	Chl-a (D5C2)		Ocean colour (chlorophyll-a concentration) (EOV Particulate matter)	
Dissolved oxygen	Dissolved oxygen (D5C5, D6C3, D6C5, D7C2)	dissolved oxygen	oxygen (CV)	
Transparency	Transparency (D5C4)	Secchi depth		
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	
current velocity	current regime (D1C6)		current (CV)	
current direction	current regime (D1C6)		current (CV)	
contaminant concentration in water	Concentrations of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
depth			bathymetry (EOV ocen subsurface currents)	
flow rate				

Table A16. List of ecological variables identified as of priority to monitor the coralligenous community and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor coralligenous community (associated to Habitat 1170 Reefs)	MSFD	WFD	EOV	EBV
percentage cover of benthic species	Benthic species coverage (D6C5)			
density				habitat structure
biomass	Benthic species biomass (D6C5)			population abundance
abundance	Representative specie abundance (D1C2, D1C3, D1C4)	Abundance of invertebrate fauna		population abundance
	Benthic species abundance (D6C5)			
biometric measures				
spatial distribution	Benthic habitat distribution (D6C5)			ecosystem extent and fragmentation
phenological measures				phenology
community structure	Benthic species age structure (D6C5)	Composition of invertebrate fauna		
	Benthic species size structure (D6C5)			
presence and size of erect Anthozoa				
percentage of necrotic tissues				
texture of the calcareous matrix				
number of taxa per functional group	Trophic guild group composition (D4C1)			taxonomic diversity
	Trophic guild species abundance (D4C1)			
genetic diversity				allelic diversity
dissimilarity between species				

presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
number/percentage cover of damaged organisms/substrate	Benthic habitat distribution (D6C5)			
	Benthic habitat extent (D6C5)			
	Benthic habitat volume (D6C5)			
abundance of opportunistic species				
habitat characterization	Benthic habitat distribution (D6C5)			
	Benthic habitat extent (D6C5)			
	Benthic habitat volume (D6C5)			
rugosity (structural complexity)	Substrate type (D6C5)			
	Substrate morphology (D6C5)			
presence/quantity of mucilage and number of events				

Table A17. List of pressure variables identified as of priority to monitor the coralligenous community and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor coralligenous community (associated to Habitat 1170 Reefs)	MSFD	WFD	EOV	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
contaminant concentration in in water and sediments	Concentrations of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
spatial and temporal variation of hydrographical conditions	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C1)			
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions (D7C2)			
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance (D6C3)			

spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			

Table A18. List of oceanographic variables identified as of priority to monitor the coralligenous community and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor coralligenous community (associated to Habitat 1170 Reefs)	MSFD	WFD	EOV	EBV
temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	EOV Subsurface temperature	
salinity	salinity (D1C6)		salinity (EOV nutrients)	
Chl-a	Chl-a (D5C2)		Ocean colour (chlorophyll-a concentration) (EOV Particulate matter)	
Dissolved oxygen	Dissolved oxygen (D5C5, D6C3, D6C5, D7C2)	dissolved oxygen	EOV oxygen	
turbidity	Turbidity (D5C4)			
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	
current velocity	current regime (D1C6)		EOV ocean subsurface currents	
current direction	current regime (D1C6)		EOV ocean subsurface currents	
Nutrient concentration in water	Nutrient concentrations (D5C1)	Total nitrogen		
		Total phosphorus		
		Soluble reactive phosphorus		
	organic carbon (D6C5)	Organic content of the bed		
depth			bathymetry (EOV ocen subsurface currents)	
PAR				
slope				
geographic orientation respect to currents				
percentage cover of sediment				
sedimentation rate				

Table A19. List of ecological variables identified as of priority to monitor *Caretta caretta* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Caretta caretta*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
Abundance	Representative species abundance (D1C2, D1C4, D1C5)		count data (SbV)	population abundance
Sex	Representative species sex structure (D1C3)		sex (SbV)	population structure by age/size class
Age	Representative species age structure (D1C3)		age (SbV)	population structure by age/size class
Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	Representative species fecundity rate (D1C3)			demographic traits
	Representative species survival rate (D1C3)			
	Mortality rate of anthropogenetic activities (D1C1)			
	Injury rate of anthropogenetic activities (D1C1)			
	Representative species mortality rate (D1C2, D1C3)			
	Representative species injury rate (D1C2, D1C3)			
Spatial distribution			distribution (EOV)	species distribution
Dispersal	Representative species distribution (D1C4)		home range (DP) e utilization distribution (DP)	migratory behavior
Emigration and immigration rate	Migration (D1C3)		migration patterns (DP)/movement patterns (DP)	migratory behaviour
Genetic diversity				allelic diversity
Prey abundance and distribution			Prey availability/diet (CV)	
gut content				
biometric measures	Representative species size structure (D1C3)			
presence of epibiotics				

Table A20. List of pressure variables identified as of priority to monitor *Caretta caretta* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor *Caretta caretta*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV

Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	Representative species fecundity rate (D1C3)			demographic traits
	Representative species survival rate (D1C3)			
	Representative species mortality rate (D1C2, D1C3)			
	Representative species injury rate (D1C2, D1C3)			
contaminant concentration in water	concentration of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
contaminant concentration in tissues		Bioaccumulation		
signs of injuries				
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
amount of litter and micro-litter ingested	amount of litter ingested by marine animals (D10C3)			
	amount of micro-litter ingested by marine animals (D10C3)			
number of individuals which are adversely affected due to litter	Mortality rate from anthropogenic activities (D10C4)			
	Injury rate from anthropogenic activities (D10C4)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
	Effects of significant acute pollution events			

effects of significant acute pollution events on the health of individuals and the condition of habitats	on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			

Table A21. List of oceanographic variables identified as of priority to monitor *Caretta caretta* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Caretta caretta*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
temperature	Temperature (D1C6, D5C4, D7C1)	temperature	temperature (CV)	
dissolved oxygen	Dissolved oxygen (D5C5)	dissolved oxygen	dissolved oxygen (CV)	
Salinity	salinity (D1C6)		surface and subsurface salinity (EOV Oxygen)	
Chl-a	Chl-a (D5C2)		Ocean colour (chlorophyll-a concentration) (EOV Particulate matter)	
Transparency	Transparency (D5C4)	Secchi depth		
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	

Table A22. List of ecological variables identified as of priority to monitor seabird populations and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor seabirds *(S. albifrons; S. hirundo; S. sandvicensis; S. nilotica; S. caspia; L. ridibundus; L. genei; L. melanocephalus; P. aristotelis; P. yelkouan)*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
density				
Abundance	Representative species abundance (D1C2, D1C4, D1C5)		count data (SbV)	population abundance
Sex	Representative species sex structure (D1C3)		sex (SbV)	population structure by age/size class
Age	Representative species age structure (D1C3)		age (SbV)	population structure by age/size class
Birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats	Representative species fecundity rate (D1C3)			demographic traits
	Representative species survival rate (D1C3)			
	Representative species mortality rate (D1C2, D1C3)			

	Representative species injury rate (D1C2, D1C3)			
Spatial distribution			distribution (EOV)	species distribution
Dispersal	Representative species distribution (D1C4)		home range (DP) e utilization distribution (DP)	migratory behavior
Emigration and immigration rate	Migration (D1C3)		migration patterns (DP)/movement patterns (DP)	migratory behavior
Genetic diversity				allelic diversity
Prey abundance and distribution			Prey availability/diet (CV)	
biometric measures	Representative species size structure (D1C3)			
competition with other species				species interactions
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
recruitment rate				
number and distribution of nesting sites and breeding pairs				
number of feeding sites				
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms	Number of harmful algal bloom events (D5C3)			
	Duration of harmful algal blooms events (D5C3)			
	Spatial extent of harmful algal blooms events (D5C3)			

Table A23. List of pressure variables identified as of priority to monitor seabird populations and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor seabirds *(S. albifrons; S. hirundo; S. sandvicensis; S. nilotica; S. caspia; L. ridibundus; L. genei; L. melanocephalus; P. aristotelis; P. yelkouan)*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV
mortality rate from incidental by-catch or incidents with nets/fences	Mortality rate from anthropogenic activities (D1C1)			demographic traits
contaminant concentration in water	concentration of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
contaminant concentration in tissues		Bioaccumulation		
events of human disturbance				

presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
amount of litter and micro-litter ingested	amount of litter ingested by marine animals (D10C3)			
	amount of micro-litter ingested by marine animals (D10C3)			
number of individuals which are adversely affected due to litter	Mortality rate from anthropogenic activities (D10C4)			
	Injury rate from anthropogenic activities (D10C4)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			

Table A24. List of oceanographic variables identified as of priority to monitor seabird populations and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor seabirds *(S. albifrons; S. hirundo; S. sandvicensis; S. nilotica; S. caspia; L.*	MSFD	WFD	EOV Marine turtle, bird and mammal abundance and distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV)	EBV

ridibundus; L. genei; L. melanocephalus; P. aristotelis; P. yelkouan)				
temperature	Temperature (D1C6, D5C4, D7C1)	temperature	temperature (CV)	
water level				
number, frequency and period of the year of extreme events				

Table A25. List of ecological variables identified as of priority to monitor *Acipenser naccarii* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Acipenser naccarii*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
density			Number, biomass or abundance index of fish of different taxa per unit volume or area of water in a specific region, stock or population, and measured by a standard or known protocol (SbV)	
abundance	commercially-exploited species abundance (D3C3) Representative species abundance (D1C2,C4,C5)	Abundance of fish fauna	fish abundance (EOV)/fish abundance indeces (DP)	population abundance
biomass	commercially-exploited species biomass (D3C3)		number or biomass of fish by size/age/stage (SbV)	population abundance
biometric measures	commercially-exploited species size structure (D3C3)			
sex	commercially-exploited population sex structure (D3C3)			
Birth-growth-mortality rates	commercially-exploited population fecundity (D3C3) commercially-exploited population survival (D3C3) commercially-exploited population mortality/injury rates (D3C3)	Life cycle of fish fauna		demographic traits
age	commercially-exploited species age structure (D3C3)	Age structure of fish fauna	Numbers or biomass of fish by size/age/stage (SbV)	population structure by age/size class
spawning rate and stock biomass	commercially-exploited species biomass (D3C2)			demographic traits
recruitment rate				demographic traits
number of suitable sites for reproduction				
spatial distribution			fish distribution EOV	species distribution

spatial movements/migration rate	Species distribution (location) (D3C2)			migratory behavior
	Behavior including movement and migration (D3C3)			
presence/abundance/ cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
genetic diversity			fish diversity indices (DP)	allelic diversity
competition with other species				Species interactions
fishing mortality rate	commercially-exploited species mortality rate (D3C1)			
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms	Number of harmful algal bloom events (D5C3)			
	Duration of harmful algal blooms events (D5C3)			
	Spatial extent of harmful algal blooms events (D5C3)			
area covered by and structure of the suitable habitats				

Table A26. List of pressure variables identified as of priority to monitor *Acipenser naccarii* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor *Acipenser naccarii*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
contaminant concentration in tissues	level of contaminants in edible tissues (D9C1)	Bioaccumulation		
contaminant concentration in water	Concentrations of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
mortality rate from incidental by-catch	Mortality rate from anthropogenic activities (D1C1)			
estimate of illegal fishing mortality rate				

number and type of barriers to migration				
spatial and temporal variation of hydrographical conditions	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C1)			
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions (D7C2)			
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance (D6C3)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter	amount of litter ingested by marine animals (D10C3)			
	amount of micro-litter ingested by marine animals (D10C3)			

Table A27. List of oceanographic variables identified as of priority to monitor *Acipenser naccarii* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Acipenser naccarii*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV

water temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	temperature (CV)	
salinity	salinity (D1C6)		salinity (CV)	
Dissolved oxygen	Dissolved oxygen (D5C5, D6C3, D6C5, D7C2)	dissolved oxygen	oxygen (CV)	
Transparency	Transparency (D5C4)	Secchi depth		
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	
current velocity	current regime (D1C6)		current (CV)	
current direction	current regime (D1C6)		current (CV)	
nutrient concentration in water	Nutrient concentrations (D5C1)	Total nitrogen		
		Total phosphorus		
		Soluble reactive phosphorus		
depth			bathymetry (EOV ocen subsurface currents)	
flow rate				
amount of precipitation				
sediment type	substrate type (D6C5)	Particle size of the bed		

Table A28. List of ecological variables identified as of priority to monitor *Petromyzon marinus* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Ecological variables to monitor *Petromyzon marinus*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
density			Number, biomass or abundance index of fish of different taxa per unit volume or area of water in a specific region, stock or population, and measured by a standard or known protocol (SbV)	
abundance	commercially-exploited species abundance (D3C3)	Abundance of fish fauna	fish abundance (EOV)/fish abundance indices (DP)	population abundance
	Representative species abundance (D1C2,C4,C5)			
biomass	commercially-exploited species biomass (D3C3)		number or biomass of fish by size/age/stage (SbV)	population abundance
biometric measures	commercially-exploited species size structure (D3C3)		size-based indicators of fish assemblages (DP)	
Birth-growth-mortality rates	commercially-exploited population fecundity (D3C3)	Life cycle of fish fauna		demographic traits
	commercially-exploited population survival (D3C3)			
	commercially-exploited population mortality/injury rates (D3C3)			
age	commercially-exploited species age structure (D3C3)	Age structure of fish fauna	Numbers or biomass of fish by size/age/stage (SbV)	population structure by age/size class

spawning rate and stock biomass	commercially-exploited species biomass (D3C2)			demographic traits
recruitment rate				demographic traits
spatial distribution			fish distribution EOV	species distribution
spatial movements/migration rate	Species distribution (location) (D3C2)			migratory behavior
	Behavior including movement and migration (D3C3)			
presence/abundance/ cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
competition with other species				Species interactions
number of resting sites and features				
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms	Number of harmful algal bloom events (D5C3)			
	Duration of harmful algal blooms events (D5C3)			
	Spatial extent of harmful algal blooms events (D5C3)			

Table A29. List of pressure variables identified as of priority to monitor *Petromyzon marinus* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Pressure variables to monitor *Petromyzon marinus*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP), complementary EOV (CV), supporting variables (SV)	EBV
presence, abundance and percentage cover of invasive species	Established NIS composition (D2C2)			
	Established NIS abundance (D2C2)			
contaminant concentration in tissues	level of contaminants in edible tissues (D9C1)	Bioaccumulation		
contaminant concentration in water	Concentrations of contaminants (D8C1)	Pollution by all priority substances identified as being discharged into the body of water		
		Pollution by other substances identified as being discharged in significant quantities into the body of water		
mortality rate from incidental by-catch	Mortality rate from anthropogenic activities (D1C1)			

estimate of illegal fishing mortality rate				
number and type of barriers to migration				
spatial and temporal variation of hydrographical conditions	Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column (D7C1)			
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions	Spatial extent of each benthic habitat type adversely affected due to permanent alteration of hydrographical conditions (D7C2)			
intensity and spatial and temporal variation of physical disturbance	Spatial extent of physical disturbance pressures (D6C2)			
	distribution of physical disturbance pressures (D6C2)			
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance (D6C3)			
spatial extent and duration of significant acute pollution events	Spatial extent of significant acute pollution events (D8C3)			
	Duration of significant acute pollution events (D8C3)			
effects of significant acute pollution events on the health of individuals and the condition of habitats	Effects of significant acute pollution events on the health of species (D8C4)			
	Effects of significant acute pollution events on the condition of habitats (D8C4)			
Amount and weight of litter and micro-litter in the water column and on the seabed	Composition of litter (D10C1)			
	Amount of litter (D10C1)			
	Spatial distribution of litter (D10C1)			
	Composition of micro-litter (D10C2)			
	Amount of micro-litter (D10C2)			
	Spatial distribution of micro-litter (D10C2)			
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter	amount of litter ingested by marine animals (D10C3)			
	amount of micro-litter ingested by marine animals (D10C3)			

Table A30. List of oceanographic variables identified as of priority to monitor *Petromyzon marinus* and their comparison with the descriptive indicators of the MSFD and WFD and the EOVs and EBVs.

Oceanographic variables to monitor *Acipenser naccarii*	MSFD	WFD	EOV Fish abundance e distribution; sub-variable (SbV), derived product (DP),	EBV

			complementary EOV (CV), supporting variables (SV)	
water temperature	Temperature (D1C6, D5C4, D7C1)	Temperature	temperature (CV)	
salinity	salinity (D1C6)		salinity (CV)	
Dissolved oxygen	Dissolved oxygen (D5C5, D6C3, D6C5, D7C2)	dissolved oxygen	oxygen (CV)	
Transparency	Transparency (D5C4)	Secchi depth		
pH	pH/pCO2 (D1C3, D5C5)	pH	pH (EOV Inorganic carbon)	
current velocity	current regime (D1C6)		current (CV)	
current direction	current regime (D1C6)		current (CV)	
depth			bathymetry (EOV ocen subsurface currents)	
flow rate				
sediment type	substrate type (D6C5)	Particle size of the bed		

Annex II

List of the ecological, pressure and oceanographic variables monitored at each N2K site and referred to the specific target species and habitats. For each target species and habitat only those sites where these are present are considered.

Table A31. Ecological variables to monitor *Tursiops truncatus*.

Ecological variables to monitor *Tursiops truncatus*	**Data availability based on the existing monitoring programs in Cres Lošinj**			**Data availability based on the existing monitoring programs in Viški akvatorij**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
density	X			X					X	X		X
abundance	X			X					X	X		X
sex	X			X					X			X
age	X			X					X			X

birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats		x			x				x			x
recruitment rate		x			x				x			x
spatial distribution	x			x					x			x
dispersal		x			x				x			x
emigration and immigration rate	x			x					x			x
frequency, intensity, duration, spatial extent and species composition of algal blooms, including harmful species			x			x			x			x

genetic diversity		x			x				x			x
Dolphin behaviour metrics	x				x				x			x
prey abundance and distribution		x				x			x			x

Table A32. Ecological variables to monitor *Fucus virsoides*.

Ecological variables to monitor *Fucus virsoides* (associated to Habitat 1170 Reefs)	**Data availability based on the existing monitoring programs in Malostonski zaljev**		
Species and habitat level	YES	NO	I DON'T KNOW
biomass		x	
cover	x		

density	x		
abundance		x	
growth-mortality rates		x	
photosynthetic activity		x	
net primary productivity		x	
spatial distribution	x		
spawning rate		x	
spawning stock biomass		x	

biometric measures		X	
phenological measures		X	
genetic diversity		X	
settlement and recruitment rate		X	
associated organisms		X	
presence, abundance and percentage cover of invasive species		X	
density and abundance of herbivores		X	
area covered by suitable habitats and their structure		X	

cover of opportunistic species		X	
frequency, intensity, duration, spatial extent and species composition of algal blooms, including harmful species		X	

Table A33. Ecological variables to monitor seagrasses.

Ecological variables to monitor seagrasses (*Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina* associated to Habitat 1120*)	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species and habitat level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
biomass		X			X	
cover	X				X	

growth rate		X			X	
recruitment rate		X			X	
leaf elongation rate		X			X	
net primary productivity		X			X	
erosion-recolonization rate		X			X	
spatial distribution	X				X	
patch size		X			X	
biometric measures		X			X	

phenological measures		x			x	
genetic diversity		x			x	
associated organisms	x				x	
habitat characterization	x				x	
presence/abundance/percentage cover of invasive species	x				x	
density and abundance of herbivores		x			x	
biomass of epiphytes		x			x	
frequency, intensity, duration, spatial extent and species composition of algal blooms, including harmful species		x		x		

Table A34. Ecological variables to monitor *Pinna nobilis*.

Ecological variables to monitor *Pinna nobilis*	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
biometric measures	X			X					X
density	X			X					X
age		X			X				X
population size	X				X				X
birth-growth-mortality rates	X			X					X

spatial distribution	X			X					X
genetic diversity		X			X				X
spawning rate	X				X				X
settlement and recruitment rate/success	X				X				X
shell burial level and orientation		X			X				X
habitat characterization	X			X					X
associated organisms	X				X				X
mortality rate due to *Haplosporidium pinnae*	X			X					X

interaction with other species		X			X				X
presence/abundance/ cover of invasive species	X				X				X
frequency, intensity, duration, spatial extent and species composition of algal blooms, including harmful species		X			X				X

Table A35. Ecological variables to monitor *Alosa fallax*.

Ecological variables to monitor *Alosa fallax*	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
density		X			X				X		X	

abundance		X		X					X		X	
biomass		X			X				X		X	
biometric measures		X			X				X		X	
age		X			X				X		X	
birth-growth and mortality rate		X			X				X		X	
spawning rate and stock biomass		X			X				X		X	
recruitment rate		X			X				X		X	
timing and duration of the estuarine phase		X			X				X		X	

spatial distribution		X			X				X		X	
spatial movements/migration rate		X			X				X		X	
presence/abundance/ cover of invasive species		X			X				X		X	
genetic diversity		X			X				X		X	
competition with other species		X			X				X		X	
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms		X			X				X		X	

Table A36. Ecological variables to monitor coralligenous.

Ecological variables to monitor Coralligenous community (associated to Habitat 1170 Reefs)	Data availability based on the existing monitoring programs in Malostonski zaljev			Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli			Data availability based on the existing monitoring programs in Tegnue di Chioggia		
Habitat and community level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
percentage cover of benthic species		X		X			X		
biomass		X			X				X
density		X		X			X		
abundance	X			X			X		
biometric measures		X			X				X

phenological measures		x			x				x
presence and size of erect Anthozoa				x			x		
percentage of necrotic tissues		x			x				x
texture of the calcareous matrix		x			x		x		
spatial distribution	x				x		x		
community structure	x				x		x		
number of taxa per functional group/genetic diversity		x			x		x		
dissimilarity between species		x			x		x		

presence, abundance and percentage cover of invasive species	X				X				X
number/percentage cover of damaged organisms/substrate	X				X				X
abundance of opportunistic species	X				X				X
habitat characterization	X			X			X		
rugosity (structural complexity)		X			X				X
presence/quantity of mucilage and number of events	X				X				X
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms		X			X				X

Table A37. Ecological variables to monitor *Caretta caretta*.

Ecological variables to monitor *Caretta caretta*	**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
abundance			X			X
sex			X			X
age			X			X
birth-growth and mortality rate			X			X
birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats			X			X

spatial distribution			x			x
dispersal			x			x
emigration and immigration rate			x			x
genetic diversity			x			x
prey abundance and distribution			x			x
gut content			x			x
biometric measures			x			x
presence of epibiontics			x			x

Table A38. Ecological variables to monitor seabirds.

Ecological variables to monitor seabirds *(Sterna albifrons; Sterna hirundo; Sterna sandvicensis; Sterna nilotica; Sterna caspia; Larus ridibundus; Larus genei; Larus melanocephalus; Phalacrocorax aristotelis; Puffinus yelkouan)*	**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
density			X			X		X	
abundance			X			X		X	
age			X			X		X	
sex			X			X		X	

biometric measures			X			X		X	
spatial distribution			X			X		X	
dispersal			X			X		X	
emigration and immigration rate			X			X		X	
genetic diversity			X			X		X	
prey abundance and distribution			X			X		X	
competition with other species			X			X		X	
presence, abundance and percentage cover of invasive species			X			X		X	

birth-growth and mortality rate			X			X		X	
recruitment rate			X			X		X	
number and distribution of nesting sites and breeding pairs			X			X		X	
number of feeding sites			X			X		X	
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms			X			X		X	

Table A39. Ecological variables to monitor *Acipenser naccarii*.

Ecological variables to monitor *Acipenser naccarii*	**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW

density		x	
abundance		x	
biomass		x	
biometric measures		x	
age		x	
sex		x	
birth-growth and mortality rate		x	
spawning rate and stock biomass		x	

recruitment rate		x	
number of suitable sites for reproduction		x	
spatial movements/migration rate		x	
spatial distribution		x	
genetic diversity		x	
competition with other species including invasive species		x	
presence, abundance and percentage cover of invasive species		x	
fishing mortality rate		x	

frequency, intensity, duration, spatial extent and species composition of harmful algal blooms		X	
area covered by and structure of the suitable habitats		X	

Table A40. Ecological variables to monitor *Petromyzon marinus*.

Ecological variables to monitor *Petromyzon marinus*	**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW
density		X	
abundance		X	
biomass		X	

biometric measures		X	
age		X	
birth-growth and mortality rate		X	
spawning rate and stock biomass		X	
recruitment rate		X	
spatial distribution		X	
spatial movements/migration rate		X	
competition with other species		X	

presence, abundance and percentage cover of invasive species		x	
number of resting sites and features		x	
frequency, intensity, duration, spatial extent and species composition of harmful algal blooms		x	

Table A41. Pressure variables to monitor *Tursiops truncatus*.

Pressure variables to monitor *Tursiops truncatus*	**Data availability based on the existing monitoring programs in Cres Lošinj**			**Data availability based on the existing monitoring programs in Viški akvatorij**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats		x			x				x			x

interaction with fishing activities and fish farms (site fidelity, group dynamics, and seasonal and yearly occurrence)	x			x					x			x
contaminant concentration in water			x			x	x			x		
contaminant concentration in tissues		x		x					x			x
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline			x			x			x			x
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter		x			x				x			x
spatial extent and duration of significant acute pollution events			x			x			x			x
effects of significant acute pollution events on the health of individuals and the condition of habitats		x			x				x			x
type, number and proximity of vessels to dolphins	x				x				x			x
spatial distribution, temporal extent, and levels of noise pollution by traffic boats	x				x				x			x

Table A42. Pressure variables to monitor *Fucus virsoides*.

Pressure variables to monitor *Fucus virsoides* (associated to Habitat 1170 Reefs)	**Data availability based on the existing monitoring programs in Malostonski zaljev**		
Species and habitat level	YES	NO	I DON'T KNOW
presence, abundance and percentage cover of invasive species		X	
heavy metal and organic pollutant concentration in tissues		X	
effect of trampling		X	
intensity and spatial and temporal variation of physical disturbance		X	
contaminant concentration in water		X	
Amount and weight of litter and micro-litter in the water column and on the seabed		X	
spatial extent of the suitable habitat which is adversely affected through change in its biotic and abiotic structure and its functions by physical disturbance spatial and temporal variation of hydrographical conditions		X	

spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions		X	
spatial extent and duration of significant acute pollution events		X	
effects of significant acute pollution events on the health of individuals and the condition of habitats		X	

Table A43. Pressure variables to monitor seagrasses.

Pressure variables to monitor seagrasses (*Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina* associated to Habitat 1120*)	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species and habitat level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
presence/abundance/percentage cover of invasive species	X				X	
contaminant concentration in water and sediments		X			X	
area cover destructed by anchoring-trawling					X	
intensity and spatial and temporal variation of physical disturbance	X				X	
spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic	X				X	

structure and its functions by physical disturbance						
spatial and temporal variation of hydrographical conditions		X			X	
spatial extent of each habitat type adversely affected due to alteration of hydrographical conditions		X			X	
spatial extent and duration of significant acute pollution events		X			X	
effects of significant acute pollution events on the health of individuals and the condition of habitats		X			X	
heavy metal and organic pollutant concentration in tissues		X			X	
Amount and weight of litter and micro-litter in the water column and on the seafloor		X			X	

Table A44. Pressure variables to *Pinna nobilis*.

Pressure variables to monitor *Pinna nobilis*	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW

presence/abundance/ cover of invasive species	X				X				X
heavy metal and organic pollutant concentration		X		X					X
heavy metal and organic pollutant concentration in tissues		X				X			X
signs of injury	X					X			X
mortality rate due to anchoring-fishing-diving		X				X			X
spatial and temporal variation of hydrographical conditions		X		X			X		
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions		X				X			X
spatial extent and duration of significant acute pollution events		X				X			X
effects of significant acute pollution events on the health of individuals and the condition of habitats		X				X			X
intensity and spatial and temporal variation of physical disturbance	X					X			X
spatial extent of the suitable habitat which is adversely affected through change in its biotic and abiotic structure and its functions by physical disturbance		X				X			X

Amount and weight of litter and micro-litter in the water column and on the seafloor		X				X			X

Table A45. Pressure variables to monitor *Alosa fallax*.

Pressure variables to monitor *Alosa fallax*	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
contaminant concentration in tissues		X				X			X		X	
fishing mortality rate		X				X			X		X	
number and type of barriers to migration		X				X			X		X	
intensity and spatial and temporal variation of physical disturbance		X				X			X		X	
spatial extent of the suitable habitat which is adversely affected through change in its biotic and abiotic structure and its functions by physical disturbance		X				X			X		X	
spatial and temporal variation of hydrographical conditions		X		X			X				X	

spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions		X				X			X		X	
spatial extent and duration of significant acute pollution events		X				X			X		X	
effects of significant acute pollution events on the health of individuals and the condition of habitats		X				X			X		X	
presence/abundance/ cover of invasive species		X			X				X		X	
		X				X			X		X	
Amount, weight and type of litter ingested		X				X			X		X	
Amount and weight of litter and micro-litter in the water column and on the seafloor		X				X			X		X	

Table A46. Pressure variables to monitor coralligenous.

Pressure variables to monitor Coralligenous community (associated to Habitat 1170 Reefs)	Data availability based on the existing monitoring programs in Malostonski zaljev			Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli			Data availability based on the existing monitoring programs in Tegnue di Chioggia		
Habitat and community level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
presence, abundance and percentage cover of invasive species	X				X				X
					X				X
contaminant concentration in water and sediments		X		X					X
				X					X
composition, amount and spatial distribution of litter and micro-litter on the seabed	X					X			X
intensity and spatial and temporal variation of physical disturbance	X					X			X
spatial extent of the suitable habitat which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance	X					X			X
spatial and temporal variation of hydrographical conditions		X		X			X		

spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions		X				X			X
spatial extent and duration of significant acute pollution events		X				X			X
effects of significant acute pollution events on the health of individuals and the condition of habitats		X				X			X

Table A47. Pressure variables to monitor *Caretta caretta*.

Pressure variables to monitor *Caretta caretta*	**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
contaminant concentration in water	X					X
	X					X
contaminant concentration in tissues			X			X
birth-growth and mortality rate/mortality rate from incidental by-catch or incidents with boats			X			X
signs of injuries			X			X

composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline			X			X
amount of litter and micro-litter ingested			X			X
number of individuals adversely affected due to litter			X			X
spatial extent and duration of significant acute pollution events			X			X
effects of significant acute pollution events on the health of individuals and the condition of habitats			X			X

Table A48. Pressure variables to monitor seabirds.

Pressure variables to monitor seabirds ***(Sterna albifrons; Sterna hirundo; Sterna sandvicensis; Sterna nilotica; Sterna caspia; Larus ridibundus; Larus genei; Larus melanocephalus; Phalacrocorax aristotelis; Puffinus yelkouan)***	**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
contaminants in water	X					X	X		
	X					X		X	

contaminants in tissues			X			X		X	
events of human disturbance			X			X		X	
mortality rate from incidental by-catch or incidents with nets/fences			X			X		X	
presence, abundance and percentage cover of invasive species		X				X		X	
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline			X			X		X	
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter			X			X		X	
spatial extent and duration of significant acute pollution events			X			X		X	
effects of significant acute pollution events on the health of individuals and the condition of habitats			X			X		X	

Table A49. Pressure variables to monitor *Acipenser naccarii*.

Pressure variables to monitor *Acipenser naccarii*	**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW

contaminant concentration in water		X	
contaminant concentration in tissues		X	
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline		X	
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter		X	
estimate of illegal fishing mortality rate		X	
mortality rate from incidental by-catch		X	
number and type of barriers to migration		X	
presence, abundance and percentage cover of invasive species		X	
intensity and spatial and temporal variation of physical disturbance		X	
spatial extent of the suitable habitat which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance		X	
spatial and temporal variation of hydrographical conditions		X	
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions		X	

spatial extent and duration of significant acute pollution events		X	
effects of significant acute pollution events on the health of individuals and the condition of habitats		X	

Table A50. Pressure variables to monitor *Petromyzon marinus*.

Pressure variables to monitor *Petromyzon marinus*	**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW
contaminant concentration in water	X		
contaminant concentration in tissues		X	
composition, amount and spatial distribution of litter and micro-litter in water, on seabed and coastline		X	
the amount of litter and micro-litter ingested, the number of individuals which are adversely affected due to litter		X	
presence, abundance and percentage cover of invasive species		X	

number and type of barriers to migration		X	
mortality rate from incidental by-catch		X	
intensity and spatial and temporal variation of physical disturbance		X	
spatial extent of the suitable habitat which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance		X	
spatial and temporal variation of hydrographical conditions		X	
spatial extent of the suitable habitat adversely affected due to alteration of hydrographical conditions		X	
spatial extent and duration of significant acute pollution events		X	
effects of significant acute pollution events on the health of individuals and the condition of habitats		X	

Table A51. Oceanographic variables to monitor *Tursiops truncatus*.

Oceanographic variables to monitor *Tursiops truncatus*	**Data availability based on the existing monitoring programs in Cres Lošinj**			**Data availability based on the existing monitoring programs in Viški akvatorij**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
temperature			X			X	X			X		
dissolved oxygen			X			X	X			X		
Salinity			X			X	X			X		
Chl-a			X			X		X		X		
Transparency			X			X	X			X		
pH			X			X	X			X		
nutrient concentration in water and sediments			X			X		X		X		

Table A52. Oceanographic variables to monitor *Fucus virsoides*.

Oceanographic variables to monitor *Fucus virsoides* (associated to Habitat 1170 Reefs)	**Data availability based on the existing monitoring programs in Malostonski zaljev**		
Species and habitat level	YES	NO	I DON'T KNOW
air and water temperature	X		
salinity	X		
PAR			X
Chl-a	X		
Dissolve oxygen	X		
Transparency	X		
pH	X		
type of substratum	X		
wind exposure	X		
wave exposure	X		
slope	X		
current velocity	X		

current direction	X		
nutrient concentration in water and sediments	X		
relative exposure index (REI)		X	

Table A53. Oceanographic variables to monitor seagrasses.

Oceanographic variables to monitor seagrasses (*Cymodocea nodosa, Posidonia oceanica, Nanozostera noltii, Zostera marina* associated to Habitat 1120*)	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species and habitat level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
temperature	X			X		
salinity	X			X		
PAR		X			X	
Chl-a	X			X		
Dissolve oxygen	X			X	X	
Transparency	X			X		

pH	X			X		
wave exposure	X					X
depth	X				X	
current velocity	X				X	
current direction	X				X	
sediment type	X				X	
sedimentation rate			X		X	
nutrient concentration in water and sediments	X			X		
Redox potential			X			X
Oxygen concentration in sediments			X		X	
Water flow rate			X		X	
Seawater level	X				X	
organic matter in sediments			X		X	

Table A54. Oceanographic variables to monitor *Pinna nobilis*.

Oceanographic variables to monitor *Pinna nobilis*	Data availability based on the existing monitoring programs in Malostonski zaljev			Data availability based on the existing monitoring programs in Tegnue di Chioggia			Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
current velocity	X			X				X	
current direction	X			X				X	
wave exposure	X			X				X	
temperature	X			X			X		
pH	X			X			X		
dissolved oxygen	X			X			X		
salinity	X			X			X		
sediment type	X			X				X	
Sedimentation rate			X			X		X	
transparency	X			X			X		
Redox potential			X			X		X	
chl a	X			X				X	

nutrient concentration in water and sediments	X			X				X	
organic matter in sediments			X			X		X	

Table A55. Oceanographic variables to monitor *Alosa fallax*.

Oceanographic variables to monitor *Alosa fallax*	**Data availability based on the existing monitoring programs in Malostonski zaljev**			**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
salinity	X			X			X			X		
water temperature	X			X			X			X		
dissolved oxygen	X			X			X			X		
current velocity and direction	X				X		X				X	
depth	X				X		X				X	
pH	X			X			X			X		
Chl-a	X				X		X			X		
transparency	X				X		X				X	

flow rate			X		X				X		X	
contaminant concentration in water			X		X		X			X		

Table A56. Oceanographic variables to monitor coralligenous.

Oceanographic variables to monitor Coralligenous community (associated to Habitat 1170 Reefs)	Data availability based on the existing monitoring programs in Malostonski zaljev			Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli			Data availability based on the existing monitoring programs in Tegnue di Chioggia		
Habitat and community level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
current velocity	X				X		X		
current direction	X				X		X		
temperature	X			X			X		
pH	X			X			X		
PAR			X	X			X		
Chl-a	X				X		X		
dissolved oxygen	X			X			X		

salinity	X			X			X		
depth	X			X			X		
slope	X			X					X
geographic orientation respect to currents	X			X					X
turbidity	X				X		X		
percentage cover of sediment	X				X		X		
sedimentation rate			X		X				X
nutrient concentration in water and sediments	X				X		X		

Table A57. Oceanographic variables to monitor *Caretta caretta*.

Oceanographic variables to monitor *Caretta caretta*	**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
temperature	X			X		
dissolved oxygen	X			X		

Chl-a		X		X		
salinity	X			X		
Transparency		X		X		
pH	X			X		

Table A58. Oceanographic variables to monitor seabirds.

Oceanographic variables to monitor seabirds *(Sterna albifrons; Sterna hirundo; Sterna sandvicensis; Sterna nilotica; Sterna caspia; Larus ridibundus; Larus genei; Larus melanocephalus; Phalacrocorax aristotelis; Puffinus yelkouan)*	**Data availability based on the existing monitoring programs in Trezze San Pietro e Bardelli**			**Data availability based on the existing monitoring programs in Tegnue di Chioggia**			**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW	YES	NO	I DON'T KNOW
water level		X		X					
temperature	X			X			X		
number, frequency and period of the year of extreme events		X				X			

Table A59. Oceanographic variables to monitor *Acipenser naccarii*.

Oceanographic variables to monitor *Acipenser naccarii*	Data availability based on the existing monitoring programs in Parco Delta del Po		
Species level	YES	NO	I DON'T KNOW
salinity	X		
pH	X		
transparency		X	
air and water temperature	X		
dissolved oxygen	X		
depth		X	
current velocity and direction		X	
water flow rate		X	
nutrient concentration in water			
amount of precipitation			X
sediment type		X	

Table A60. Oceanographic variables to monitor *Petromyzon marinus*.

Oceanographic variables to monitor *Petromyzon marinus* - Referred to N2K site Parco Delta del Po	**Data availability based on the existing monitoring programs in Parco Delta del Po**		
Species level	YES	NO	I DON'T KNOW
salinity	X		
water temperature	X		
dissolved oxygen	X		
current velocity and direction		X	
transparency		X	
pH	X		
depth		X	
water flow rate		X	
type of substrate		X	